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HOW IT WORKS

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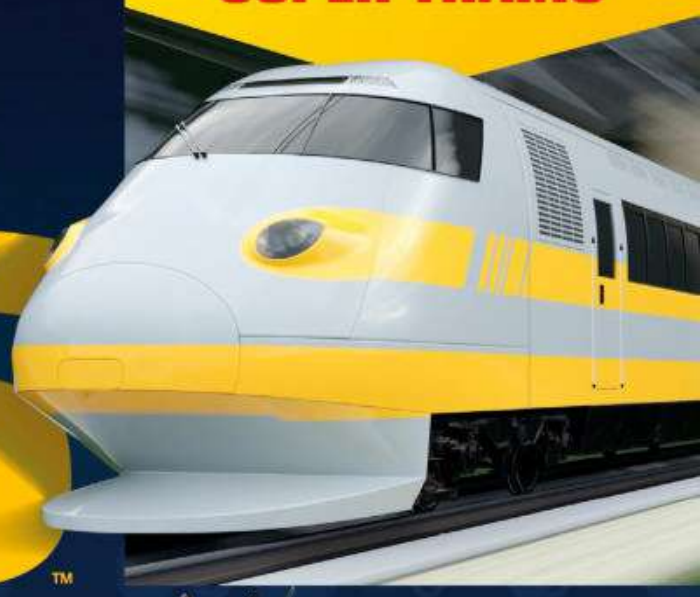

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FUTURE
ISSUE 136

+ CAN YOU QUIT BEING KING? MAKE A BUG HOTEL SPY SATELLITE ANATOMY

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30
Mr Bean
and BRILLIANT*
The beloved ~~oddball~~ Mr Bean famously drives a 1976 British Leyland Mini 1000 on his adventures. The 'Citron' lime green coloured car is fitted with numerous ~~bizarre~~ GENIUS security features including a bolted latch and padlock on the driver's door and a removable steering wheel.
← Not on this tiny model!
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ISSUE **136**

WELCOME

The magazine that feeds minds!

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"I was 10 or 11 when I stumbled across a chatroom whose members taught me how to hack"

Cyber warfare, page 22

Meet the team...

Nikole
Production Editor
NASA uses Hubble and an array of other telescopes to take amazing images of space. Turn to page 70 to see some of the best.

Scott
Staff Writer
Is vaping any better than smoking? Discover the science of nicotine addiction and the mystery vaping illness on page 32.

Baljeet
Research Editor
We're under constant surveillance from satellites in the sky. Learn the secrets of these spying eyes on page 52.

Duncan
Senior Art Editor
Nuclear weapons are the most deadly on Earth. On page 60 we explore their history and the development of their destructive power.

Ailsa
Staff Writer
Every day we use hundreds of litres of water, but where does it go after leaving our homes? Follow its journey on page 50.

If anything, the internet has become an even wilder digital frontier for all the exploring we've done in the last 30 years. Hackers, phishing scammers, botnet hijackers and computer viruses either hide behind screens and in devices thousands of miles from you, or in nooks of code on innocuous websites. You can protect your computer by arming yourself with the knowledge of how these nasties – both digital and human varieties – work in this issue of **How It Works**. We've also spoken to a computer hacker who's turned his previous illegal online activities into a force for good. Enjoy the issue!

Ben Editor

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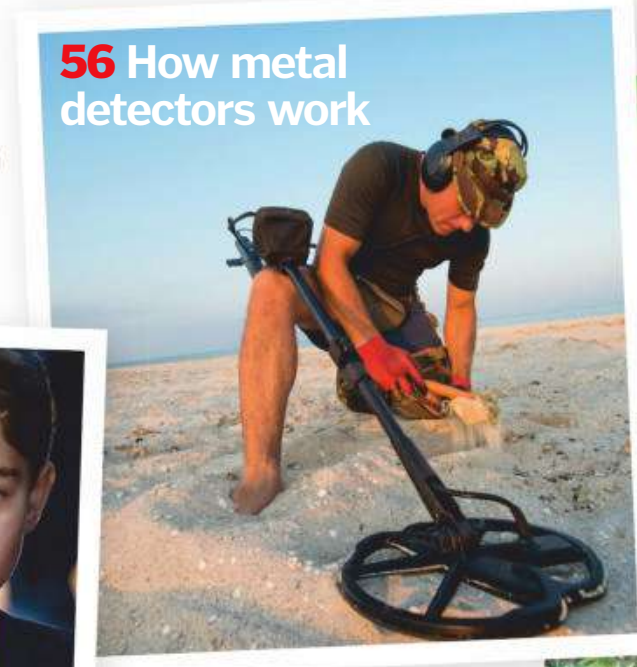

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AR ZONE!

Scan the QR code with your device's camera or download a free QR code reader app. Many iPhone and Android devices include a QR reader

When you see the AR ZONE! logo at the top of a page, use your phone to scan the QR code, which looks like this

Hold your mobile device over the image and watch it come to life! Your device needs to be connected to the internet for this to work

HOW THE AUGMENTED REALITY WORKS

After being launched by the QR code, the app reads anything you point your device's camera at 30 times a second, searching for distinctive shapes we've trained it to recognise. When it sees a familiar picture, it overlays the augmented-reality 3D image we've previously uploaded on your screen.

MEET THIS ISSUE'S EXPERTS...

Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

Mark Smith
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

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Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

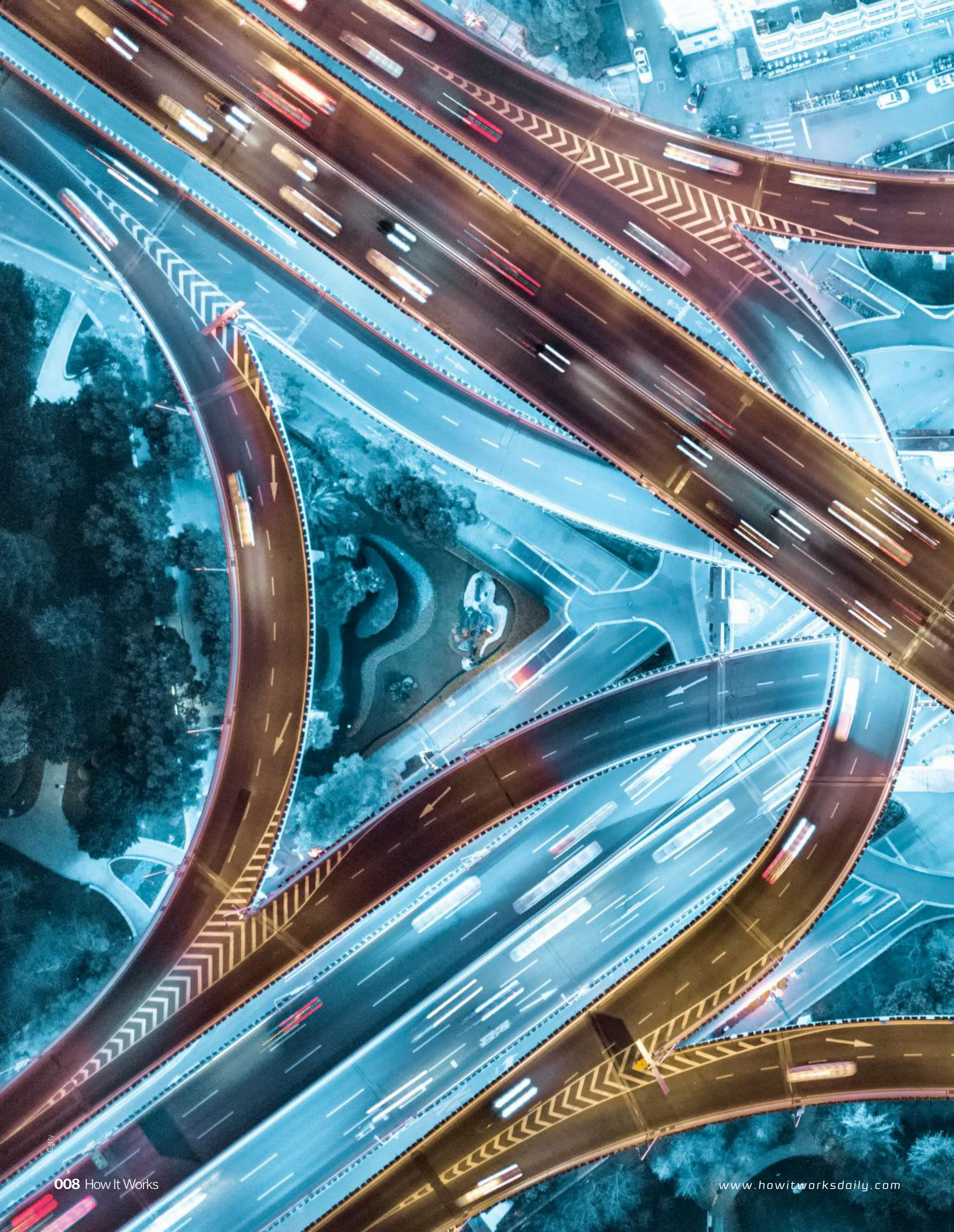
Steve Wright
Steve has worked as an editor on various publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.

Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.

FRIDGE INVADER

These dewy hair-like strands might look like they belong among grass blades on a crisp morning. However, they live a little closer to home. Found in the forgotten punnet of raspberries at the back of the fridge, *Rhizopus stolonifer*, also known as 'black bread mould', forms a woolly coat around expired fruit and vegetables. The hair-like structures, called sporangiophore, reach out holding tiny black and white spores so the fungus can spread. This furry photo was captured by Juliet Evans for The Royal Photographic Society's 2019 science photography competition. You can find out more about this year's entries at **rps.org**.

© Juliet Evans



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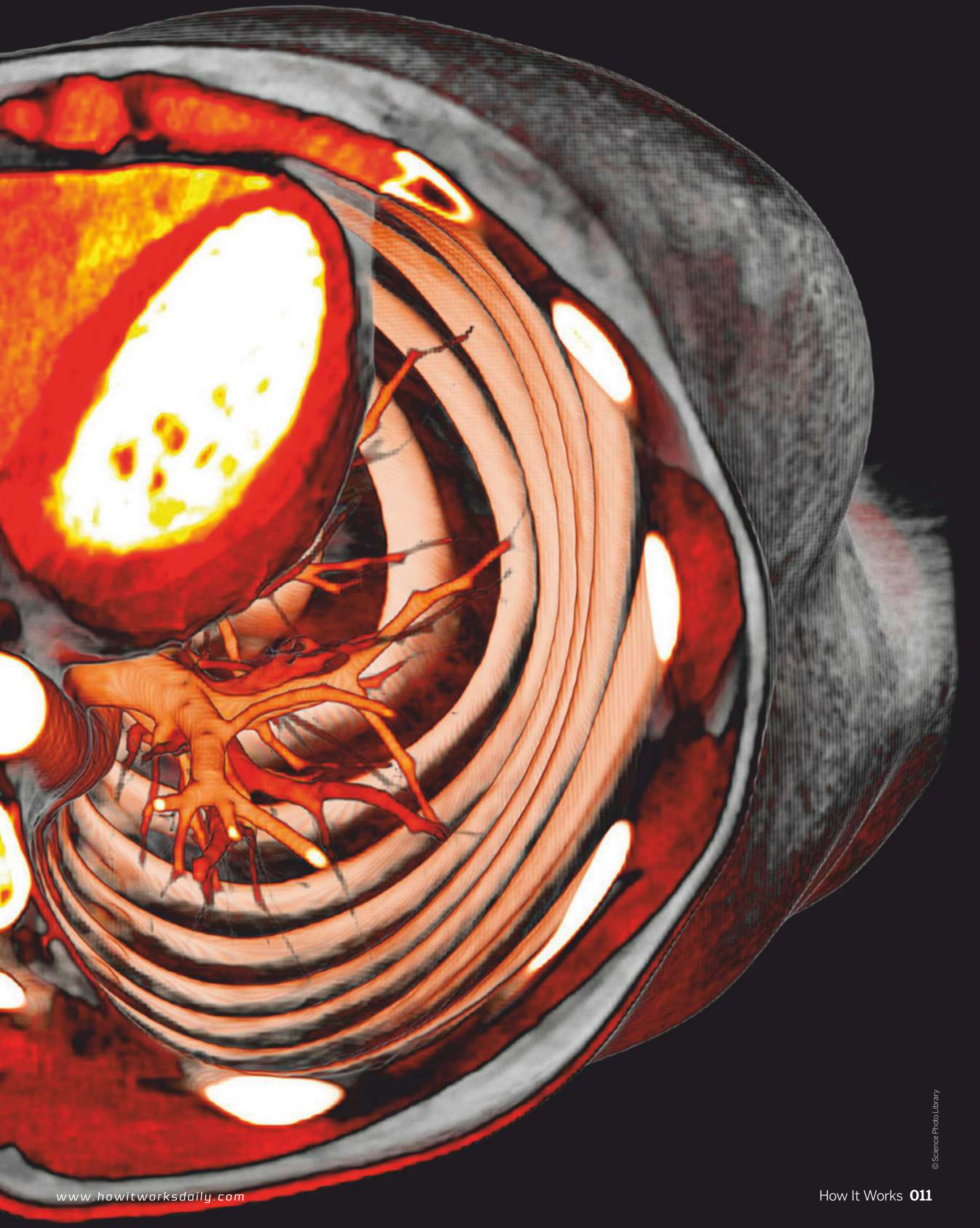
CRAWLING TRAFFIC, HIDDEN DRAGON

Lit up like arteries in Shanghai's circulatory system, roads meet in a symmetrical junction called the Chengdu Bei Lu and Yan'an Lu intersection. Illuminated by indigo LED lights, this intertwined highway supports over 2.5 million cars currently driving on the streets of Shanghai. During construction between 1995 and 1999, this example of architectural excellence found itself waking a sleeping dragon – or so legend has it. Upon trying to insert one of many supporting pillars, digging crews hit an unexplainable hurdle, and despite their incessant pounding the ground beneath wouldn't budge. As the story goes, a priest summoned to the construction site informed engineers of the mystical beast's displeasure, suggesting a way to restore its slumber that would allow the pillar to be erected. To honour the legend, the central pillar was gilded with metallic dragons by designer Zhao Zhirong. It's now known as the 'Nine Dragon Pillar'.

HUMAN CHEST CAVITY

Using X-rays to take a peek inside the human body can reveal some spectacular images, and this coloured axial computed tomography (CT) scan is no exception. CT scanners use a rotating ring equipped with an X-ray source to snap image 'slices' through the body. This is only possible because of the way X-rays interact with the tissue in our bodies. Bone, for example, absorbs more of the radiation than soft tissue, revealing them on an X-ray image. To see the soft tissue such as organs, however, a contrast agent – typically iodine-based – is injected into the bloodstream to absorb the X-ray radiation and reveal the networks of blood vessels and vital organs within our bodies.



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ANIMALS

Jellyfish found to release venom 'bombs'

Words by **Nicoletta Lanese**

Upside-down jellyfish pulse on the ocean floor, their frilly arms stretched skyward as they release venom-filled blobs of mucus into the surrounding water where the slime 'stings' passing swimmers, new research reveals.

These jellyfish (*Cassiopea xamachana*) look like strange, squidgy plants stuck to the ocean floor, and they tend to assemble in groups that resemble bizarre flowerbeds. Upside-down jellies can be found living in the mangrove forests and lagoons of southern Florida, Hawaii, the Indo-Pacific Ocean and the Caribbean. Snorkellers who visit those areas sometimes develop a strange itching sensation on their skin, as if the water itself stung them. But until now, nobody knew the actual cause.

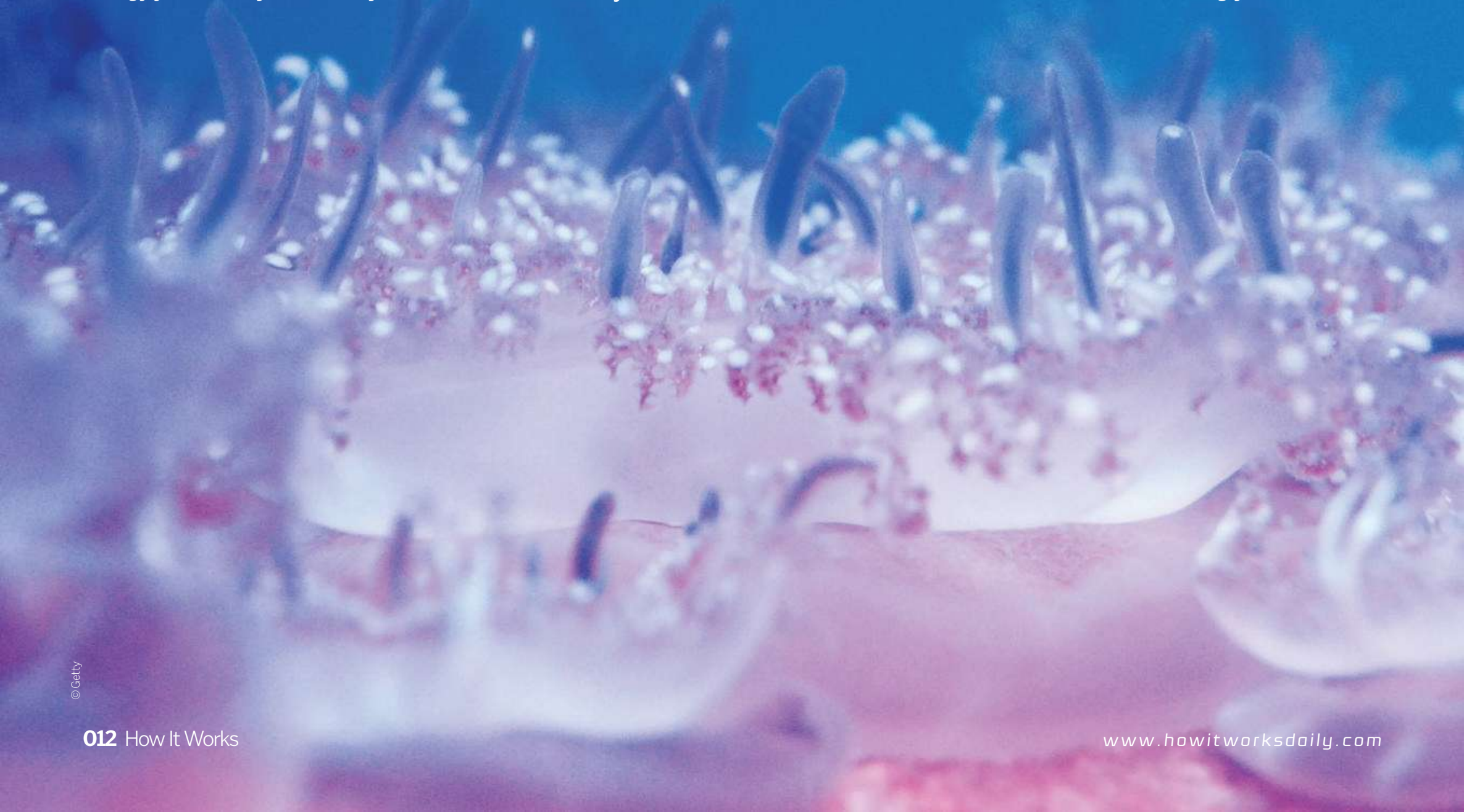
Researchers for the *Communications Biology* journal may have finally cracked this case. From their spot on the seafloor, these upside-down jellyfish deploy an arsenal of cellular 'bombs' armed with stinging cells called nematocytes. When these bombs make contact with a passing swimmer they release venom that irritates the skin. But if one of these bomb bumps into a tiny brine shrimp (you might know them as 'sea monkeys'), one of the upside-down jellies' favourite snacks, its venom kills the animal on contact.

Those familiar with stinging water may have heard of so-called sea lice, creatures often blamed for the painful sensation associated with upside-down jellies. Sea lice are parasites that prey on fish, but the term serves as a colloquial 'catchall' for anything that causes water to sting.

None of the proposed explanations held up to scrutiny. "We initially thought that there would maybe be some tentacle bits from other jellyfish" floating through the water, perhaps detached during a massive spawning event, as can happen, said Cheryl Ames, a museum research associate and an associate professor of applied marine biology at Tohoku University in Japan.

With the mystery still unsolved, the scientists realised that whenever they were stung, they were swimming near upside-down jellyfish at low tide while the jellies pumped out murky clouds of mucus. To find out if these oddball jellies were the culprit, the researchers looked at samples of the jellies' mucus under high-resolution microscopes. They spotted tiny, jelly-filled spheres floating within the fluid that appeared to be packed with cells and algae.

The team uncovered one stray study from 1908 that mentioned the strange spheres, but those researchers had wrongly identified the



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structures as parasites of the jellyfish. By analysing the molecules and proteins in the spheres, Ames' team confirmed that the spheres came from the jellyfish and were dispersed from spoon-shaped pads on the animals' arms.

Stinging cells called nematocytes coat the outermost layer of the bumpy spheres; when touched these cells leak venom from long, stringy structures on their surfaces, stinging unwary creatures that run into them. In addition to stinging nematocytes, cells covered in hairlike threads called cilia stud the surface of the spheres. These cilia wave in the water and act as tiny propellers that send the spheres spinning off in every direction. The team named the free-wheeling spheres 'cassiosomes', after the Cassiopeia genus.

If you see upside-down jellies while you're swimming, it may be best to admire the squishy creatures from a distance to avoid floating through their snotty clouds of stinging spheres.

Mucus produced by these upside-down jellyfish can be seen floating above their frilly arms

Heartbeat rhythms are as unique as fingerprints, and lasers can identify their signature beats

© Getty

TECH

Military laser identifies you by your heartbeat

Words by **Mindy Weisberger**

The US military could soon spot you in a crowd – not by your face or your gait, but by your unique heartbeat rhythm. The Pentagon recently developed and tested a laser that can scan and distinguish the pitter-patter of your heart from up to 200 metres away.

Dubbed 'Jetson', the name recalls the popular sci-fi cartoon family the Jetsons, who inhabited a world full of futuristic gadgets. But unlike the handy household devices from the show, the new laser system was built for combatting terrorism and was created by the Pentagon at the request of the US Special Forces, *MIT Technology Review* (*MTR*) reported.

Unlike some types of identification techniques that rely on biometrics – unique anatomical or behavioural traits – the subjects of Jetson's heartbeat-detecting infrared laser can be far away from the scanner. The laser can even sense heartbeats through clothing, according to *MTR*.

Retina shape and fingerprints have long been recognised as biomarkers that are individually unique and can be used for identification. Over the past decade technologies have emerged that can detect even more biomarkers, such as vein patterns and body odour, as well as heartbeats.

Jetson reads heartbeats from a distance through vibrometry, a contact-free technique that measures the vibration of a surface. Algorithms then translate patterns in a heartbeat into a unique cardiac signature, according to *MTR*.

However, the present version of Jetson requires 30 seconds to conduct scans and gather heartbeat data – a limitation that somewhat hampers the technology's usefulness when people are moving, *MTR* reported.

Other types of long-range biometric identification, such as facial recognition, can be derailed if faces are even partially obscured. In contrast, cardiac patterns are difficult for an individual to change deliberately. Experiments demonstrated that Jetson can identify individuals with 95 per cent accuracy, said Steward Remaly, a retired US Army colonel and a counter-terrorism program manager.

IN ASSOCIATION WITH
LIVESCIENCE

A new study may help answer one of the universe's biggest mysteries

SPACE

Space-time ripples could explain the universe

Words by **Yasemin Saplakoglu**

One of the universe's biggest mysteries - why there is more matter than antimatter - may be a step closer to being answered. That answer, in turn, could explain why everything from atoms to black holes exist.

Billions of years ago, soon after the Big Bang, cosmic inflation stretched the tiny seed of our universe and transformed energy into matter. Physicists think inflation initially created the same amount of matter and antimatter, which annihilate each other on contact. But then something happened that tipped the scales in favour of matter, allowing everything we can see and touch to come into existence – and a new study suggests that the explanation is hidden in very slight ripples in space-time.

"If you just start off with an equal component of matter and antimatter, you would just end up with having nothing" because antimatter and matter have equal but opposite charge, said Jeff Dror, the lead researcher at the University of California, Berkeley. "Everything would just annihilate."

Obviously everything did not annihilate, but researchers are unsure why. The answer might involve very strange elementary particles known as neutrinos, which don't have electrical charge and can thus act as either matter or antimatter.

One idea is that about a million years after the Big Bang, the universe cooled and underwent a phase transition, an event similar to how boiling water turns liquid into gas. This phase change prompted decaying neutrinos to create more matter than antimatter by some "small, small amount," Dror said. But "there are no very simple ways – or almost any ways – to probe [this theory] and understand if it actually occurred in the early universe".

But Dror and his team, through theoretical models and calculations, figured out a way we might be able to see this phase transition. They proposed that the change would have created extremely long and extremely thin threads of energy called 'cosmic strings' that still pervade the universe. Dror and his team realised that these cosmic strings would most likely create very slight ripples in space-time called gravitational waves. Detect these gravitational waves and we can discover whether this theory is true.

The strongest gravitational waves in our universe occur when a supernova, or star explosion, happens; when two large stars orbit each other or when two black holes merge, according to NASA. But the proposed gravitational waves caused by cosmic strings would be much tinier than the ones our instruments have detected before.

However, when the team modelled this hypothetical phase transition under various temperature conditions that could have occurred during this phase transition, they made an encouraging discovery. In all cases cosmic strings would create gravitational waves that would be detectable by future observatories, such as the European Space Agency's Laser Interferometer Space Antenna (LISA), the proposed Big Bang Observer and the Japan Aerospace Exploration Agency's Deci-hertz Interferometer Gravitational wave Observatory (DECIGO).

© Alamy

ANIMALS

Lizard parasites jump from mother to offspring

Words by **Nicoletta Lanese**

A newfound species of parasitic worm wiggles its way into the brains of baby lizards long before the reptiles hatch.

How do the nematodes break into developing lizard brains? They sneak in through the lizard mothers' ovaries, new research finds.

Parasitic nematodes that prey on mammals can sometimes jump from mother to offspring through the placenta in utero or through breast milk after birth. But until now no one thought that reptiles could also pass down their parasites from mother to offspring; evidence suggested that because they lay eggs, animals like lizards are less vulnerable to certain routes of parasitic transmission.

But much to scientists' surprise, the discovery of worms in lizard embryos suggests that reptilian eggs aren't as impenetrable as once thought."I was shocked when I saw something moving in the embryo's brain, despite having dissected many lizard eggs before," said lead author Nathalie Feiner, an evolutionary biologist at Lund University in Sweden. While studying common wall lizards (*Podarcis muralis*) across Europe, Feiner and her colleagues routinely dissect and examine developing lizard embryos and find most to be worm-free. However, one population of common wall lizards in the Pyrenees mountain range turned out to be riddled with nematodes.

Wondering where the worms came from, the researchers examined the lizard mothers and found nematodes wriggling in the animals' ovaries. Typically nematodes invade the intestines of common wall lizards, but the authors hypothesised that this newfound species adapted to thrive in the reproductive system of females. The worms in the ovary infiltrate the embryos of the developing lizards and enter their brains before a hard egg shell forms around the animal.

The authors allowed several infected lizard embryos to develop to maturity, noting that "infected lizard embryos develop normally and hatch with nematodes residing in their braincase". The animals appear healthy when first hatched – parasites aside – but the researchers did not monitor the lizards further to see how their health and behaviour might be affected as they mature, the authors added.

Scientists found parasitic worms in the brains of common wall lizard embryos

© Getty

GLOBAL EYE

© DARPA

An artist's concept of DARPA's Glide Breaker anti-hypersonic-weapon system

TECH

New technology targets hypersonic missile threats

Words by **Elizabeth Howell**

Aerojet Rocketdyne is working on technology to help knock high-speed manoeuvrable vehicles out of the sky under a new contract from the US Defense Advanced Research Projects Agency (DARPA). Since 2018 DARPA has been developing a hypersonic defence interceptor system called Glide Breaker, which is designed to intercept threatening vehicles moving at hypersonic speeds – at least five-times faster than the speed of sound – in Earth's upper atmosphere. Aerojet Rocketdyne will develop 'enabling technologies' for Glide Breaker under the recently announced contract, which is worth around £15.2 million ($19.6 million).

"Advancing hypersonic technology is a national security imperative," Eileen Drake, Aerojet Rocketdyne CEO and president, said in a statement. "Our team is proud to apply our decades of experience developing hypersonic and missile propulsion technologies to the Glide Breaker programme."

Developing technologies that can knock incoming missiles or other fast-moving vehicles out of the sky is a priority for militaries around the world. The US has worked on numerous similar ideas over the years, some of which never got off the ground.

One of the most famous mothballed concepts was the Strategic Defense Initiative (SDI), a complex, space-based system championed by President Ronald Reagan; opponents derisively dubbed it 'Star Wars'.

IN ASSOCIATION WITH LIVESCIENCE

PLANET EARTH

Ocean currents are getting faster

Words by **Stephanie Pappas**

Ocean currents are moving faster today than they did two decades ago. Recent research, published in the journal *Science Advances*, found that this acceleration is occurring around the globe, with the most noticeable effects in the tropical latitudes. The enhanced speed isn't just at the ocean's surface, but is occurring as deep as 2,000 metres.

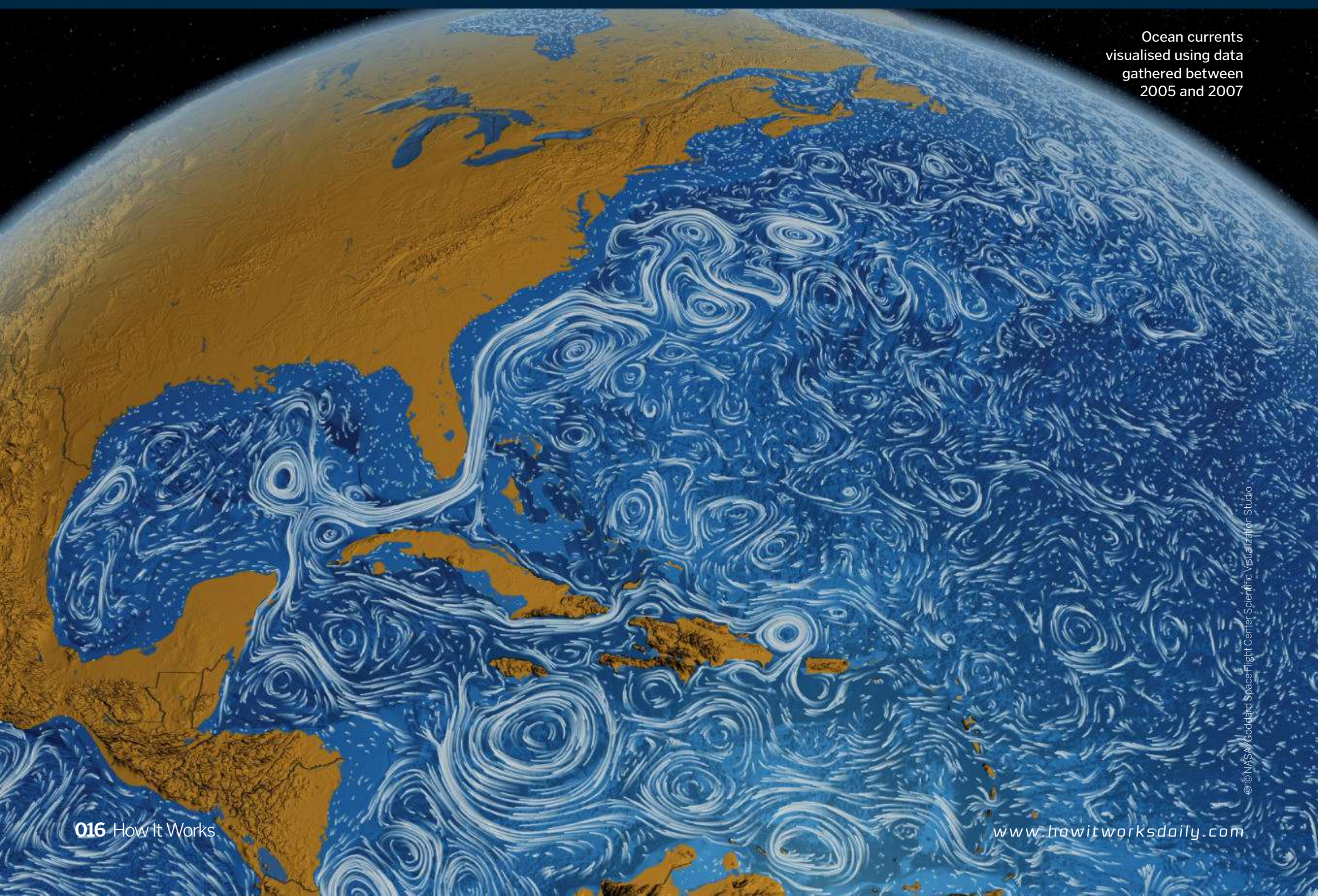
"The magnitude and extent of the acceleration in ocean currents we detected throughout the global ocean and to 2,000-metre depth was quite surprising," said Janet Sprintall, an oceanographer at the at the University of California, San Diego. "While we expected some response to the increased winds over the past two decades, that the acceleration was above and beyond that was an unexpected response that is most likely due to global climate change."

Winds over the ocean have been picking up at a rate of 1.9 per cent per decade, the researchers found. This increase in wind speed transfers energy to the ocean's surface, and subsequently deeper waters. About 76 per cent of the upper 2,000 metres of the oceans have seen an increase in kinetic energy since the 1990s. Overall ocean current speeds have crept up about 5 per cent per decade since the early 1990s, the study found.

Researchers were interested in understanding global changes to ocean currents because prior research had turned up a confusing picture. For example, currents in the subtropics that transfer energy from the equator to the poles have intensified over the last century. But some major regional currents, such as the Kuroshio in the western North Pacific Ocean, show little evidence of acceleration.

The team reanalysed old ocean current data recorded across the last few decades and pulled new information from the Argo mission, a scientific project that uses thousands of autonomous, missile-shaped floats to gather information about ocean temperature, salinity and currents.

The speedup isn't immediately obvious because ocean currents move very slowly. For example, the South Equatorial Current in the Pacific Ocean moves at only 1.6 kilometres an hour, so it would only speed up 0.08 kilometres per hour in a decade. Given the enormous amount of water that's on the move, it takes a significant amount of energy input to create that acceleration. These changes are much larger than what would be expected from natural variability, which suggests that global warming could be causing the increased speed.



Ocean currents visualised using data gathered between 2005 and 2007

© NASA Goddard Space Flight Center Scientific Visualization Studio

Building the X-59 is only phase one of the entire project. In phase two further testing, certifications and acoustic validation will occur

© NASA/Lockheed Martin

SPACE

NASA's supersonic jet could be built by late 2020

Words by **Chelsea Gohd**

NASA's new experimental supersonic X-plane is on a fast track to flying. The plane, officially named X-59 QueSST in 2018 and often referred to as just X-59, was greenlit for final assembly during a critical design review in 2019. With this plane NASA aims to create an ultra-quiet craft that can travel over land faster than the speed of sound.

In 2020, Lockheed Martin, who NASA commissioned to build the plane, plans to mate the aircraft and completely finish the building process by the end of the year, a company representative said. "It's moving very fast on the shop floor in terms of manufacturing and production," the company said.

This follows a year of serious progress as the plane's wings have been assembled at Lockheed Martin Skunk Works in Palmdale, California, and innovative systems for the craft continue to develop.

After the "mating of the aircraft and final assembly," the representative said, "we'll take the airframe to do some proof testing and get some other parts installed, do some test runs of the systems and then roll it out." Once the plane is all together, it will take its first flight in 2021, the representative added.

But will a plane that travels at supersonic speeds, or faster than the speed of sound, really be quiet enough to avoid causing a major disturbance? According to the representative, the team behind the plane is confident that the craft will be ultrafast and ultra quiet.

"We're very confident. All kinds of modelling simulations and predictions align, so we believe, based on these models and simulations we've run, that it will achieve that low-boom sound once it reaches supersonic speeds."

To ensure that this is the case and that the plane not only works correctly and reaches these incredible speeds, but also remains quiet enough to not be a public nuisance, additional testing will follow the completion of the plane in 2020.

HISTORY

Dozens of rare ancient Egyptian coffins unearthed

Words by Laura Geggel

Archaeologists have discovered 83 graves from ancient Egypt, but the human remains weren't interred in sarcophagi, as is often the case. Instead the deceased were buried in clay coffins, according to the Egyptian Ministry of Antiquities.

80 of the graves date to the civilisation of Bhutto, or Lower Egypt, during the first half of the fourth millennium BCE. The burials were found during archaeological excavations in the Dakahlia Governorate of northern Egypt, not too far from the Mediterranean Sea.

The team also found three graves from the Naqada III period, which lasted from about 3200 to 3000 BCE. It's unusual to find clay coffins in Dakahlia from Naqada III, Mostafa Waziri, the secretary-general of the Supreme Council of Antiquities, said in a statement. In other parts of Egypt during that time, elite people were usually buried in mud-brick tombs or wood coffins, while poorer people were often buried in shallow holes, according to University College London.

The Naqada culture is old, even by Egyptian standards, dating to predynastic Egypt during the Chalcolithic era, or Copper Age. The new discovery indicates that many people lived in this area at that time, said Waziri, who suspects that even more graves will be found at the site.

© Egyptian Ministry of Antiquities

This individual had a number of grave goods. It appears that the red pigment ochre covered part of the grave when the deceased was laid to rest

HISTORY

World's largest turtle shell discovered

Words by **Laura Geggel**

An 8-million-year-old turtle shell unearthed in Venezuela measures nearly 2.4 metres long, making it the largest complete turtle shell known to science, a recent study reported.

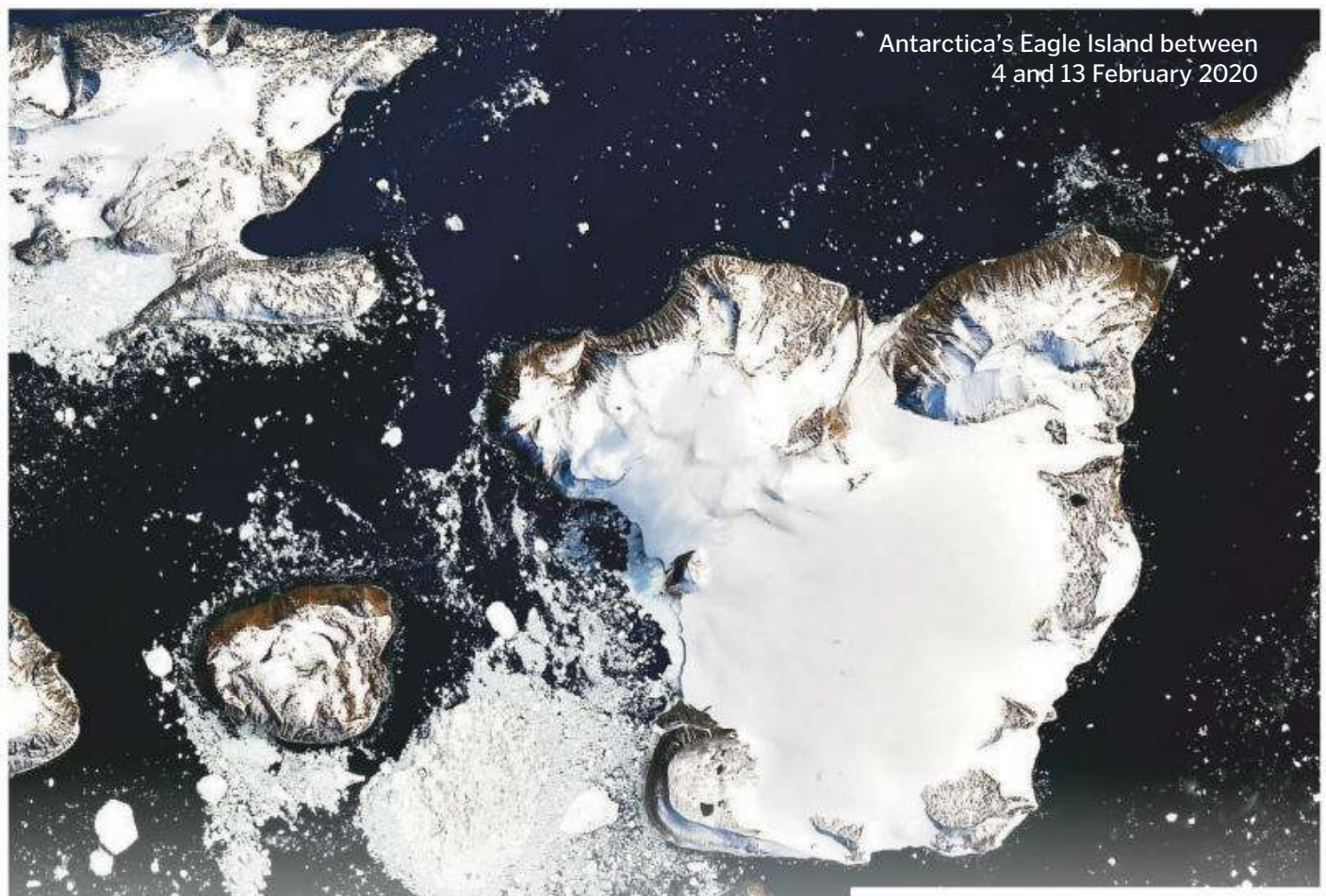
This shell belonged to an extinct beast called *Stupendemys geographicus* which lived in northern South America during the Miocene epoch, which lasted from 12 million to 5 million years ago.

***S. geographicus* weighed an estimated 1,145 kilograms, almost 100 times the size of its closest living relative, the Amazon river turtle (*Peltocephalus dumerilianus*), and twice the size of the largest living turtle, the marine leatherback sea turtle (*Dermochelys coriacea*).**

Its impressive shell makes this ancient creature "one of the largest, if not the largest turtle that ever existed," said study senior researcher Marcelo Sánchez-Villagra, the director of the Paleontological Institute and Museum at the University of Zurich. The species likely achieved its colossal size thanks to the warm wetlands and lakes in its habitat, Sánchez noted.

© Edwin Cadena

Venezuelan palaeontologist Rodolfo Sánchez and a male carapace of *Stupendemys geographicus*



Antarctica's Eagle Island between 4 and 13 February 2020

PLANET EARTH

Antarctica loses huge amounts of ice in record heat

© NASA Earth Observatory

Words by **Brandon Specktor**

It's easy to forget that Antarctica is technically a desert until you see it without snow, but a new pair of satellite images shared by NASA's Earth Observatory makes that stark reality as clear as ice.

NASA's Landsat-8 satellite snapped the two images of Eagle Island, a small island off Antarctica's northwestern tip, on 4 and 13 February 2020, bookending a period of record-high temperatures in the southernmost continent. Between the two images a significant amount of the island's glacial ice disappeared, revealing huge swaths of the barren brown rock underneath.

According to glaciologist Mauri Pelto, a professor of environmental science at Nichols College in Massachusetts, the island lost about 20 per cent of its seasonal snow accumulation in just a few days.

"You see these kinds of melt events in Alaska and Greenland, but not usually in Antarctica," Pelto explained.

The melt coincided with not just one, but two record-high temperatures recorded on Antarctica this month. On 6 February a research station on the northern edge of the Antarctic Peninsula – the finger of land on the continent's northwest tip, closest to South America – recorded a new record-high temperature of 18.3 degrees Celsius – surpassing the previous record of 17.5 degrees Celsius that was set in March 2015.

Days later on 9 February, researchers on the nearby Seymour Island saw their thermometers hit 20.75 degrees Celsius, setting another all-time high for the continent.

As the new images show, those high temperatures caused significant melting on nearby glaciers. According to Pelto, Eagle Island lost nearly 1.5 square kilometres of snowpack to the heat, creating several large ponds of bright-blue meltwater at the island's centre.

While every season has its highs, this summer has been especially warm for Antarctica, Pelto said. The continent has already seen two heatwaves this season – one in November 2019 and one in January 2020 – reminding us that significant melt events like these are becoming much more common as global warming continues unchecked.

HEALTH

Scientists discover massive bacteria-eating viruses

Words by **Yasemin Saplakoglu**

Huge bacteria-killing viruses lurk in ecosystems around the world, from hot springs to freshwater lakes and rivers. Now, a group of researchers has discovered some of these so-called bacteriophages that are so large and so complex that they blur the line between living and nonliving, according to new findings.

Bacteriophages, or 'phages' for short, are viruses that specifically infect bacteria. Phages and other viruses are not considered living organisms because they can't carry out biological processes without the help and cellular machinery of another organism.

That doesn't mean they are innocuous: phages are major drivers of ecosystem change because they prey on populations of bacteria, alter their metabolism, spread antibiotic resistance and carry compounds that cause disease in animals and humans, according to scientists from the University of California.

To learn more about these sneaky invaders, the scientists searched through a DNA database that they created from samples they and their colleagues collected from nearly 30 different environments around the world, ranging from the guts of people and Alaskan moose to a South African bioreactor and a Tibetan hot spring.

From that DNA they discovered 351 huge phages that had genomes four or more times larger than the average genome of phages. Among those was the largest phage found to date with a genome of 735,000 base pairs – the pairs of nucleotides that make up the rungs of the DNA molecule's 'ladder' structure – or nearly 15-times larger than the average phage. For reference, the human genome contains about 3 billion base pairs.

These phages are "hybrids between what we think of as traditional viruses and traditional living organisms" such as bacteria and archaea, said Jill Banfield, a University of California, Berkeley professor of Earth and planetary science. This huge phages' genome is much larger than the genomes of many bacteria.

The researchers found that many of the genes coded for proteins are yet unknown to us. They found that the phages had a number of genes that are not typical of viruses but are typical of bacteria. Some of these genes are part of a system that bacteria use to fight viruses and was later adapted by humans to edit genes – a technique called CRISPR-Cas9.

Scientists don't know for sure, but they think that once these phages inject their DNA into bacteria, the phages' own CRISPR system strengthens the CRISPR system of the bacteria. In that way the combined CRISPR system could help to target other phages – getting rid of the competition.

A newly discovered virus is blurring the lines between living and nonliving

© Shutterstock

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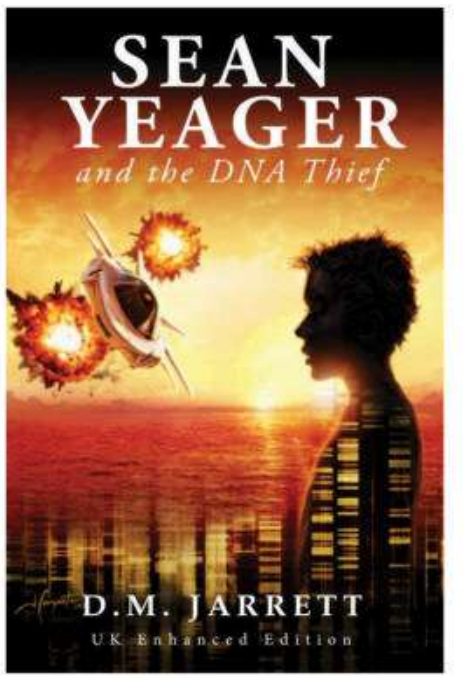
Intruder alert! Code 10! Scramble all Agents!



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'A compelling read with lots of action.'

'Fast-paced, exciting, and humorous.'

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www.SeanYeager.com

WISH LIST

The latest **garden** gadgets

Landroid robotic lawn mower

■ Price: **From £499 (approx. $644)**
www.worx-europe.com

Bringing lawn mowing into the 21st century, the Landroid by Worx is showing how robotic autonomy can help you out in the garden. Much like the indoor Roomba vacuum, the Landroid uses a wireless connection to navigate your lawn with ease. With built-in ultrasonic sensors, this self-driving robot detects the array of obstacles and narrow turns in your garden. Landroid also learns on the job, calculating the area of your lawn, your grass' growth rate and soil composition for intelligent mowing.

©Worx

Smart Cara CS-10

■ Price: **£399 (approx. $516)**
www.smartcaraeurope.com

One of the best ways to feed your garden is with a nutritious meal of compost. Garden composters are typically large wooden structures in which household food waste is left over time to mulch down into the perfect fertiliser, a process which can take months or even years. However, the Smart Cara has been created to turn food scraps into plant food in only three to four hours. Simply place the waste into the countertop drum and the Smart Cara will dehydrate and pulverise it into a powder to be sprinkled on your flowerbeds.

©Smart Cara

Smart Rain Gauge

■ Price: **£59.99 / $79.99**
www.netatmo.com

If you've been guilty of overwatering your plants then the Smart Rain Gauge by Netatmo may be the product for you. Simply placed into your lawn, this high-tech rainfall gauge provides real-time readings on rainfall data and precipitation levels straight to your smartphone. This enables you to know how much water your garden has had before you reach for the watering can.

©Netatmo

Gardena smart sensor control set

Price: **£299.99 (approx. $387)**
www.gardena.com

Paired with your smartphone, this high-tech irrigation system takes the hassle out of watering your garden. Set up to six watering cycles per day to keep your plant life hydrated while you're away from home. With the accompanying smart sensor you can monitor your garden's soil moisture, temperature, light intensity and receive frost alerts straight to your smartphone through the Gardena app, available for iOS and Android.

© Gardena

© green feathers

WiFi Bird Box Camera

Price: **From £129 (approx. $167)**
www.green-feathers.co.uk

One of the joys of having a wildlife-friendly garden is witnessing the animal visitors that take advantage of it. However, getting an up-close view can be hard to achieve, especially when watching birds. With the WiFi Bird Box Camera by Green Feathers, you can now get a front-row seat to your garden wildlife. Simply mount the camera onto a bird box and stream live footage straight to your smartphone and make recordings to share with the whole family.

WheelEasy™

Price: **$189.99 (approx. £147)**
www.allsopgarden.com

If you're a keen gardener and spend a lot of time lifting heavily rubble and garden waste in metal wheelbarrows, the WheelEasy™ by Allsop Home and Garden might be a welcome addition to your gardening equipment. By simply dropping the handles on the ground, the collapsible heavy-duty nylon cart falls to the floor for ground-level loading. Simply pick up the handles and carry your garden waste away.

© WheelEasy

APPS & TOOLS

SmartPlant

Developer: **SnappTech**
Price: **Free / Google Play / App Store**

As a digital plant expert, this app has all the info you need to care for your plant life, find the best species for your garden and identify pests and diseases.

My Soil

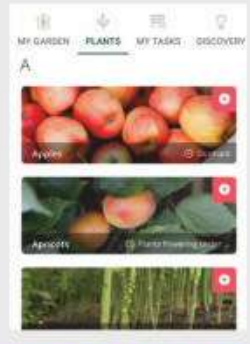
Developer: **British Geological Survey**
Price: **Free / Google Play**

Using this soil map app, you can find out the properties of your garden through GPS and share information such as soil description and pH with other users.

Grow Your Own

Developer: **Royal Horticultural Society**
Price: **Free / Google Play / App Store**

If you're a keen vegetable grower, the RHS has put together this growers encyclopedia for gardeners of all skills and abilities.



Garden Organizer

Developer: **Gleyco**
Price: **Free / Google Play**

Keeping track of the life cycles of your garden plants can be tricky, but with this app, you can receive schedules on watering and seeding for each.

HOW SAFE IS YOUR COMPUTER?

CYBER WARFARE

CRIMINALS SPIES, HACKERS AND VIRUSES: HOW THE BATTLES OF THE FUTURE WILL BE FOUGHT ACROSS THE INTERNET

Words by **Mark Smith**

Hackers could hack into smart homes by gaining access to our smart technology

The world is in the grip of a new age of conflict. Where once ships, planes, tanks and soldiers did battle to further the goals of their own nations, now sophisticated cyber attacks are the new weapons of choice. Countries are using hackers to target power grids, financial markets and government computer systems of rival nations, all with potential results that are every bit as devastating as any bullet or bomb.

The idea of using tech to pilfer information goes back a long way, as far back as 1834, in fact, with two French brothers – the Blanc brothers – who used to earn a living trading in government bonds.

They found a way to get ahead of the competition by bribing a telegraph operator to include deliberate mistakes in messages being transmitted from Paris. This let them get a heads up on financial deals before anyone else did. But as technology got more sophisticated, so did the crimes the crooks were capable of pulling off. However, it wasn't until almost 150 years later that the first person would be charged with a cyber crime.

Back in 1981 a chap called Ian Murphy – imaginatively nicknamed Captain Zap – hacked into US telecoms company AT&T and changed its internal clock to charge off-peak fees to people making peak-time calls. Although he thought he was doing these people a favour by letting them use the phone on the cheap, the company – having lost millions of dollars – and the US government were none too impressed, so he was given 1,000 hours of community service and a fine as punishment.

These days, when you think about what most teenagers get up to with their computers it probably conjures up images of video games or Facebook – not hacking into the computers of the people who put a man on the Moon and built the Space Shuttle.

But that's exactly what 15-year-old Jonathan James decided to do. Installing backdoors – gaps in computer code that allow hackers to easily infiltrate a system – into the US Department of Defense, he was able

WANTED BY THE FBI
MAKSIM VIKTOROVICH YAKUBETS
Conspiracy; Conspiracy to Commit Fraud; Wire Fraud; Bank Fraud; Intentional Damage to a Computer
DESCRIPTION
Aliases: Maksim Yakubets, "AQUA"
Date(s) of Birth Used: May 20, 1987
Place of Birth: Ukraine
Hair: Brown
Eyes: Brown
Height: Approximately 5'10"
Weight: Approximately 170 pounds
Sex: Male
Race: White
Citizenship: Russian
REWARD
The United States Department of State's Transnational Organized Crime Rewards Program is offering a reward of up to $5 million for information leading to the arrest and/or conviction of Maksim Viktorovich Yakubets.
CAUTION
Maksim Viktorovich Yakubets is wanted for his involvement with computer malware that infected tens of thousands of computers in both North America and Europe, resulting in actual financial losses in the tens of millions of dollars.
Specifically, Yakubets was involved in the installation of malicious software known as Zeus, which was disseminated through phishing emails and used to capture victims' online banking credentials. These credentials were then used to steal money from the victims' bank accounts. On August 22, 2012, an individual was charged in a superseding indictment under the moniker "aqua" in the District of Nebraska with conspiracy to participate in racketeering

In 2019, the FBI issued warrants for the arrest of a Russian hacker group, 'Evil Corp', including Ukrainian hacker Maksim Yakubets

© Getty

to intercept and read thousands of private emails flying all over the place, including some with top-secret information. He then used what he found to steal a piece of NASA software and shut down systems for three weeks.

Cyber attacks had traditionally been carried out by lone criminals – and usually for a variety of reasons. Some like to test their skills against a system and share their successes with others in their shadowy community. Some do it purely for the money, such as Russian hacker group Evil Corp, who are thought to have stolen over $100 million (£77 million) from ordinary people around the world. Others do it for what they see as 'good reasons', such as finding gaps in a company's network so they can take steps to fix it before any serious damage is done.

The first group – the bad guys – are referred to in the hacking community as 'black hat' hackers, while the latter – who think of themselves as the 'good guys' – are called 'white hat' hackers.

Often when a black hat hacker is caught, if they're good enough at what they do, law enforcement or industry will actually give them a job tracking down other hackers and helping to fix flaws in a computer system. But as technology has become more sophisticated, hacking has become a profession with thousands employed by governments as a new tool in their arsenal of war. Often overseen by spy agencies, they're told to carry out attacks on rival countries' infrastructure and steal secret information.

In 2007, in what is believed to have been the first incident of cyber warfare, the Estonian government announced plans to move an old Soviet war memorial, but found itself under a digital assault that sent its banks and government services into meltdown. Russia was blamed, but denied any knowledge.

This evolving threat led to the creation of the US Cyber Command in 2009. Part of the US Air Force, it was placed under the command of General Keith Alexander. It was now official – the cyber threat had gone from kids in bedrooms looking to make a quick buck or prove their smarts to something that was now viewed as a threat to national security.

> "Some like to test their skills against a system"

Alexander's fears were well founded too, with the US accusing China of infiltrating large US corporations to steal their ideas, including Google in 2010, and at least 33 other corporations such as Northrop Grumman – a major weapons manufacturer. The US has also accused Iran, Russia and North Korea of being major state sponsors of cyber attacks. In total, 28 nations are suspected of state-sponsored cyber attacks, including the US.

In many ways these attacks pose more of a threat than conventional warfare. With an invasion, there are signs of military build-up: tanks need building, pilots need training. With cyber attacks, they can come at any time with the press of a button, devastating a whole country's economy or power grid in an instant.

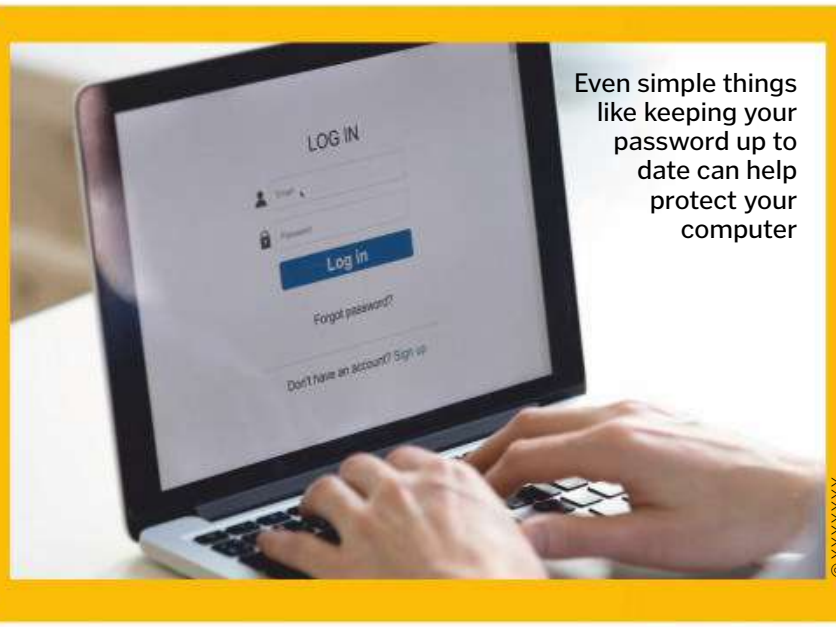
Few attacks have been as devastating or as shadowy as one that took place just a couple of years ago: the WannaCry attack.

It started just like any other morning on 12 May 2017, when at around 08.24 an unsuspecting computer user opened what appeared to be a harmless email. The email contained an attachment which, once opened, downloaded ransomware onto their system. Ransomware is computer code that's been designed to encrypt a system – scrambling all the data on a hard drive – and only unscrambles it when a user gives into the hacker's demands, such as paying money, hence the name ransomware.

If you'd been one of those affected by the WannaCry attack, you'd have logged onto your computer and seen a message asking you for money, with all of your private information such as your pictures, bank records, games, videos – everything – completely scrambled.

It began to spread around the world like wildfire. The first company to report problems was Spanish telecoms giant Telefonica, with multiple staff finding they'd been locked out of their computers.

By 11:00 the UK's National Health Service (NHS) reported problems, with 80 out of 236



Even simple things like keeping your password up to date can help protect your computer

© XXXXXX

Protecting your system from malware

Malware like WannaCry was able to spread because it exploited weaknesses in Windows that Microsoft had already released patches (software updates that fix the weaknesses) for months earlier. But not everyone had downloaded them. Those Windows updates may take a while, but they're there for a reason. Also, installing anti-virus software and a firewall will help to keep the worst malware away. Make sure you download updates for them and run scans regularly – you never know what's lurking on your hard drive.

In addition, just be sensible. Don't open emails from anyone you don't know or click links unless you know the source. Make sure you use strong passwords that are hard to guess and change them often.

Cyber attacks will sometimes try to encrypt your personal data, so make sure you've backed everything up to an external hard drive or the cloud so you don't lose them for good if you do fall foul of a hacker.

TYPES OF CYBER THREATS

There's a multitude of ways hackers can carry out their attacks

DDOS

You know how slow the internet is when there are too many people on it? A DDoS attack swarms a system with traffic, slowing or completely crashing it. The hacker will often charge a ransom to stop the attack.

PHISHING AND SPEAR PHISHING

Ever had a spam email? Phishing is an attempt to get your bank details or other secret information. Spear phishing is more targeted at you; it may use your name or pretend to be from a friend.

DRIVE BY

These types of attacks happen when a hacker implants dodgy code in a website that you visit. When you open the website it gains access to your computer through your browser.

PASSWORD ATTACK

This is when a hacker uses your passwords to gain entry to your system. They might simply guess your password or use a brute-force attack – a program which tries lots of combinations really quickly.

IP SPOOFING

This is where a hacker disguises the origin of their hack as something trustworthy, so you might think you're visiting your bank's website when it's actually a hacker's fake website stealing your login details.

MALWARE TO WATCH FOR

Hackers have got their own artificial helpers – rogue computer programs called malware

VIRUS

A type of computer code that's been designed to change a system's behaviour, usually to do something nasty. Like a real-life virus, they're also designed to replicate and spread quickly.

SPYWARE

This lurks on your computer, observing the websites you visit or the sensitive information you download. It then transmits that information back to a hacker.

TROJAN

Like the Trojan Horse in Greek history, this is code that's designed to look like something harmless. Once downloaded it gives the hacker access to your system and sensitive files.

RANSOM WARE

This is code that stops your computer operating unless you give the hacker some money to unlock your scrambled information.

WORM

While a virus needs you to download a host – like an infected word document – a worm doesn't. It's a standalone piece of code that gets into your system, often via personal emails.

© Getty

The US power grid was allegedly attacked by Russian hackers in 2018

© Courtesy of the American Public Power Assoc at on

Hacker armies are now being employed by governments for cyber warfare

© Getty

hospital trusts having their computers locked out, leading to many of its patients having to be diverted to alternative accident and emergency departments.

The attack didn't stop there. Chinese petrol stations had their payment systems cut off, German railways lost control of their passenger information system and FedEx's logistical operations were disrupted in the United States. French car maker Renault and the Russian Ministry of the Interior were also hit.

Within hours the WannaCry virus had spread to 230,000 computers in 150 countries before being stopped by an analyst who discovered a 'kill switch' that shut it down, but it is to this day regarded as one of the most destructive cyber attacks ever seen.

> *"Within hours WannaCry had spread to 230,000 computers"*

The reason the malware was able to spread so quickly is that it exploited security vulnerabilities in old versions of Microsoft Windows. This vulnerability had allegedly been discovered by US intelligence some months earlier, but instead of warning people they turned it into a cyber weapon called EternalBlue. This cyber weapon was later stolen by a hacker group called the Shadow Brokers, and it's thought it was used to help the malware spread rapidly. The US and UK governments would later single out hackers with links to North Korean intelligence agencies with the attack.

If you take a look around you, you'll probably see a smartphone, tablet, laptop or a smart TV. Maybe there's some other smart tech in your home: a doorbell that links to your phone or a thermostat you can turn up or down by text. On the drive maybe there's a car with all the mod cons like GPS. But every single one of these things could be used as a weapon in a cyber war.

We're surrounded by modern computer technology, and increasingly it's all connected to one another as part of the 'internet of things' – the tech that links smart devices together.

A 2017 briefing by US intelligence claimed connected thermostats, cameras and cookers could all be used either to spy or cause disruption if they were hacked. Only last year, the FBI warned that smart TV speakers, which are designed to listen to our voices, could be hacked for surveillance purposes.

What's clear is that whether it's in our own homes or outside on the virtual battlefield, a conflict between those who want to take control of technology will continue to rage for the foreseeable future.

200 BILLION
Estimated number of connected devices by the end of 2020

6 MONTHS
It typically takes half a year for companies to detect a hacker problem

95%
The number of breaches due to human error

THE FBI'S ONLINE 'CYBER'S MOST WANTED' LIST FEATURES OVER 100 PEOPLE

3.5 MILLION
Cyber security job vacancies by 2021

4.5 BILLION
Number of records hacked in the first part in 2018

24,000
Malicious mobile apps blocked in their thousands every day

CYBER CRIMES ARE HUGELY UNDERREPORTED BECAUSE VICTIMS ARE OFTEN TOO EMBARRASSED

Q&A

FROM CHILD HACKER TO BUG HUNTER

Tommy DeVoss started hacking aged ten and was jailed in 2000 for breaking into military computers. He now earns 'bug bounties' for finding problems in company computer systems

Why did you become a black hat hacker?
At school I would finish my work in ten minutes and spend the rest of the lesson playing on the computer. I was 10 or 11 when I stumbled across a chatroom whose members taught me how to hack – I was just a bored kid doing it for fun. I first got into trouble in high school and was ordered to stay away from computers, but I didn't. With others, I broke into secure government systems and was caught again and spent four years in prison. I was told if I got caught again then I wouldn't get out. In 2016 I discovered bug bounty programs [via the 'HackerOne' organisation] and could return to the hobby I loved, but this time working for good.

Walk us through a typical hacking attack
When hacking a website, I pick a target that has a bug bounty program and spend some time looking at and using it.

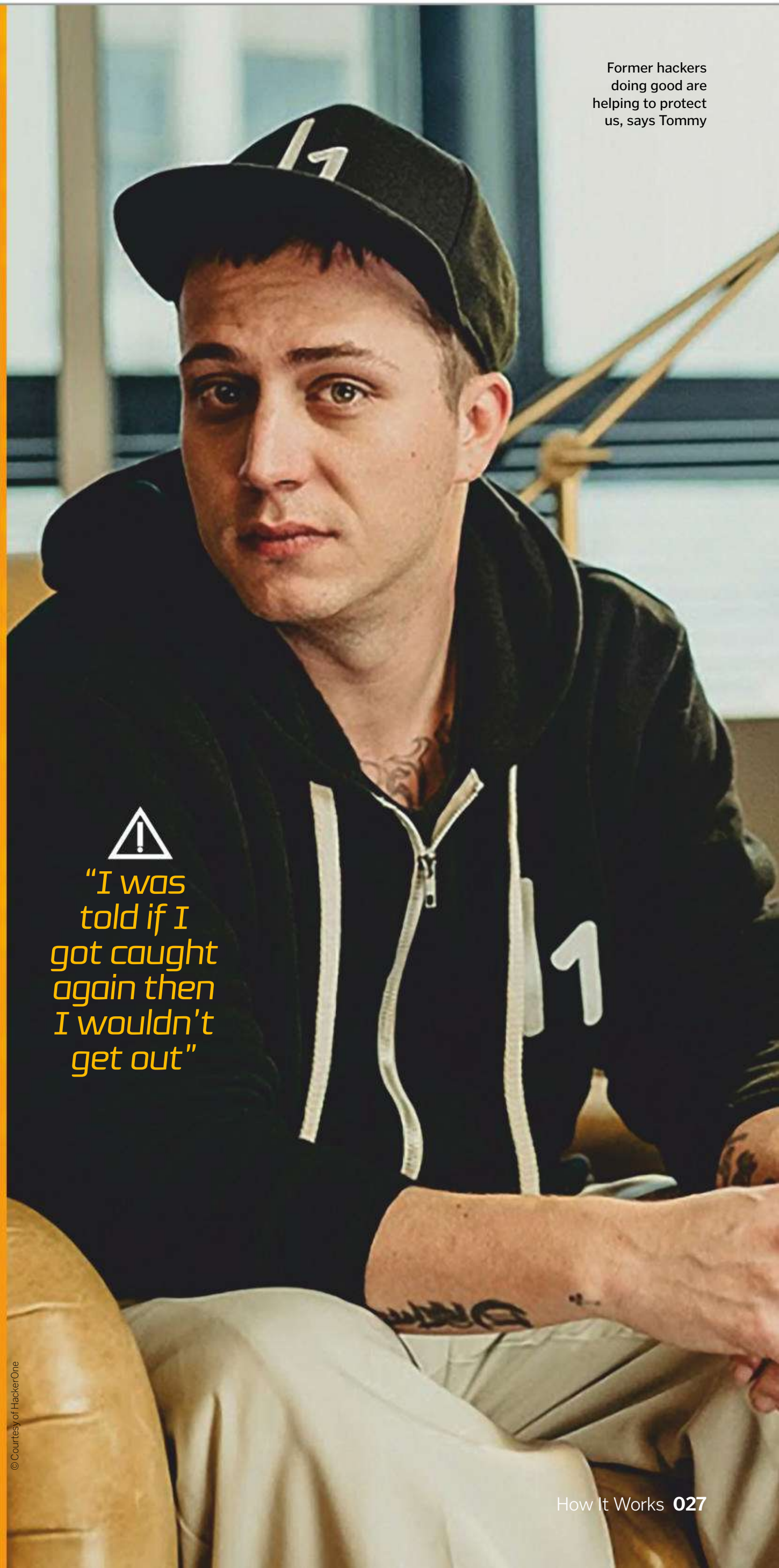
Next, I look for interesting places where you might be able to do something like upload files, or where the website tries to fetch data from another website.

I would then try to upload files that could introduce a vulnerability, for example, if there is an option to upload a profile picture. Then I could potentially upload a code execution.

If there is an area like an RSS feed generator, I can see if I can get it to pull data from an internal server that I shouldn't have access to.

How do you see the future of hacking and cyber security developing?
As more things are connected to the internet, we will see more attacks on things in the real world. 25 years ago when I started out, we used to joke about causing real-world damage; it wasn't feasible then, but it is now.

www.howitworksdaily.com



Former hackers doing good are helping to protect us, says Tommy

"I was told if I got caught again then I wouldn't get out"

© Courtesy of HackerOne

GLOBAL CYBER ATTACKS

The biggest threats of the last decade couldn't be stopped by fences and checkpoints

RUSSIA → US

LinkedIn breach

5 June 2012

Initially thought to have compromised 6.5 million passwords, in 2016 the company announced it was actually closer to 100 million. Russian hackers were thought to be behind the attack.

RUSSIA → US

Yahoo data breach

2013 and 2014

The internet giant was attacked twice with a total of 3 billion user accounts thought to have been compromised. Investigators suspect hackers tied to the Russian government were to blame.

RUSSIA → US

Hold Security breach

August 2014

IT company Hold Security claimed Russian hackers had stolen 1.2 billion logins and passwords on 420,000 websites around the world. The breach could have allowed the CyberVor hacker group to access 500 million accounts.

IRAN → UNITED KINGDOM

Attack on Parliament

June 2017

Hackers attempted to gain access to email accounts used by British Members of Parliament and their staff. The attack was originally believed to be the work of Russian or North Korean hackers, but was later blamed on Iran.

CHINA → US

Theft, plane and simple

2010 to 2015

Many experts believe China engaged in cyber breaches to steal information from Western aerospace companies, passing their intellectual property to Chinese companies which it then used to supply parts for its C919 airliner.

ISRAEL [SUSPECTED] → IRAN

Stuxnet attack

Discovered in June 2010

The mysterious Stuxnet was slipped into Iranian nuclear facilities, subtly slowing its centrifuges to quietly disrupt the enrichment process of uranium and setting its weapons programme back years. The finger of blame was pointed at Israel, although no proof has been found.

"In many ways these attacks pose more of a threat than conventional warfare"

The shadowy world of hacker groups

Cyber criminals often reside in online communities, sharing things they've learned and boasting about their 'accomplishments'.

The more hackers that work together, the bigger the feats they're able to pull off, and often they join forces for some shared goal.

One of the most infamous was the hacker group Anonymous. Branding themselves as 'hacktivists' they wore Guy Fawkes masks and claimed to take on the big corporate and government bad guys on behalf of the ordinary people of the world. But since 2015 they have all but disappeared, with fewer hacktivist attacks reported worldwide. Getting involved in political hacking is thought to be one of the reasons many of its members quit.

Hacktivist group Anonymous were fond of wearing Guy Fawkes masks on screen

© Getty

US → RUSSIA

Power grid strike

June 2019

Last year Russia claimed to have thwarted a US cyber attack on its energy infrastructure. Cyber security experts claim it could have been a retaliatory strike for a Russian intrusion on the US power grid a year earlier.

NORTH KOREA → WORLDWIDE

WannaCry

12 May 2017

The WannaCry epidemic knocked out more than 200,000 computers in 150 countries including the UK, US and Spain. Hackers with ties to North Korea were blamed.

RUSSIA → US

Hold Security breach

August 2014

CHINA → US

Theft, plane and simple

2010 to 2015

RUSSIA → WORLDWIDE

NotPetya/ExPetr

27 June 2017

The costliest worldwide ransom attack in history at an estimated $10 billion (£7.73 billion). The attack began in Ukraine and spread to Europe and the US, with the American and UK governments blaming the Russian military.

US AND UK → JAPAN

Sony PlayStation Network

20 April 2011

A total of 77 million accounts were compromised following an attack by hacker group LulzSec – a splinter group of Anonymous – with an estimated company loss of $171 million while the site was down for a month.

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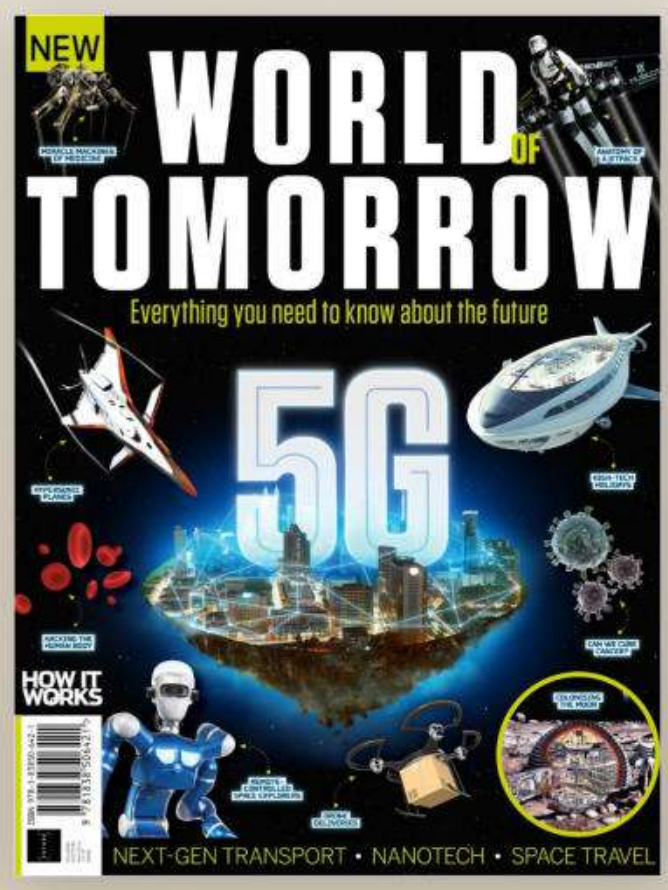
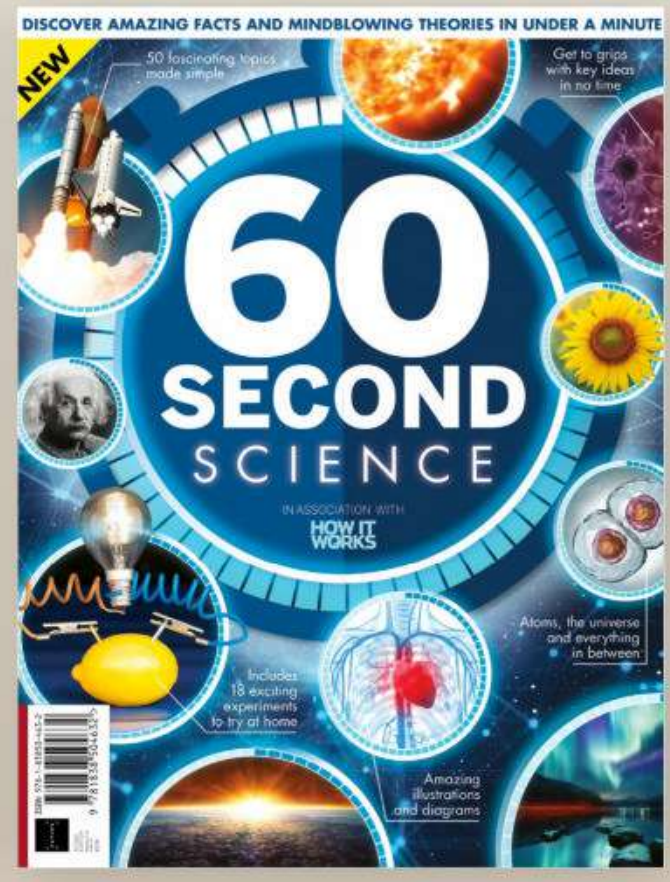


WORLD OF TOMORROW

While it's no magical artefact, this offers a glimpse into future developments in transport, medicine, entertainment and space travel based on the innovations taking place in the present day and speculations made by scientists and engineers.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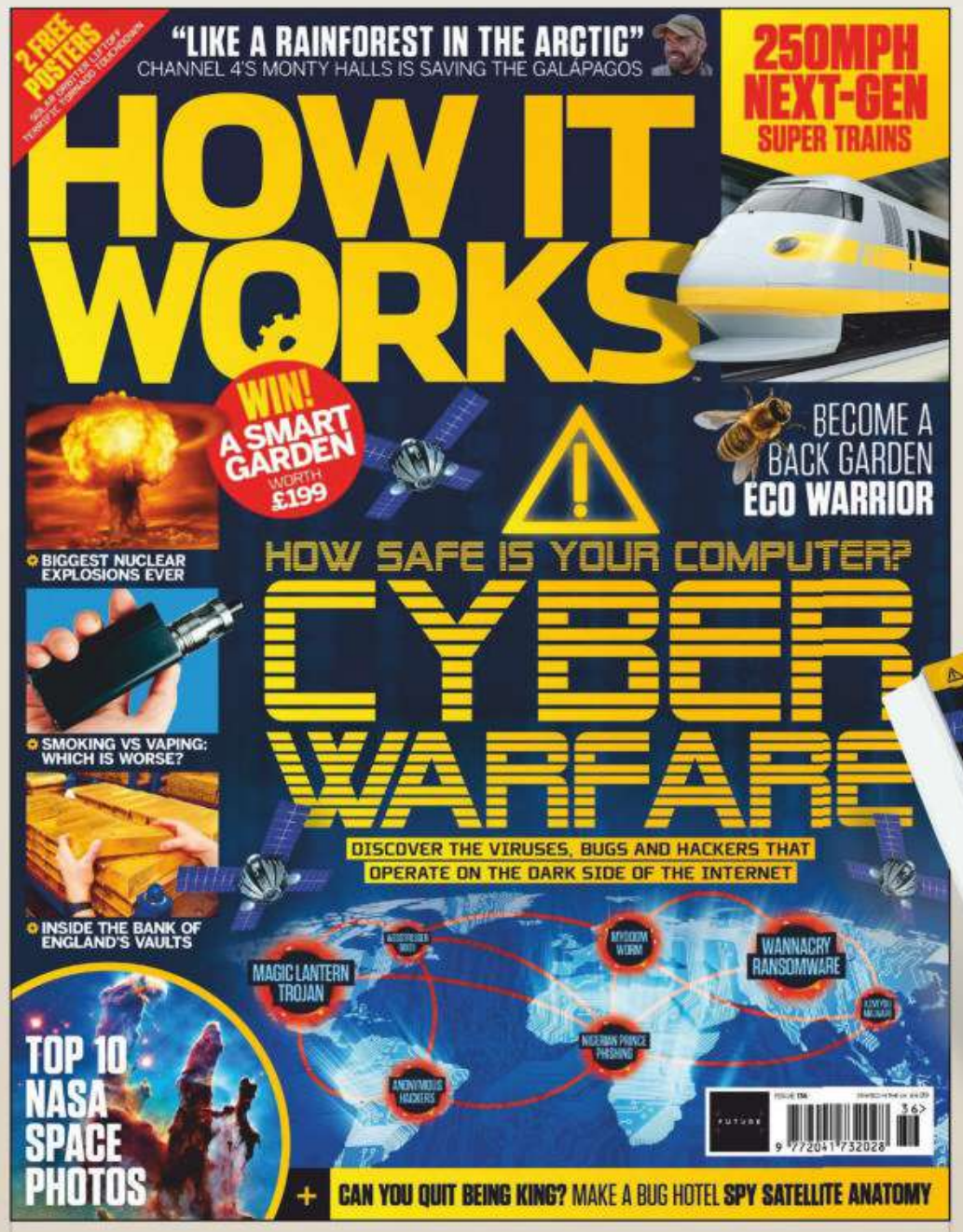
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MYDOOM WORM
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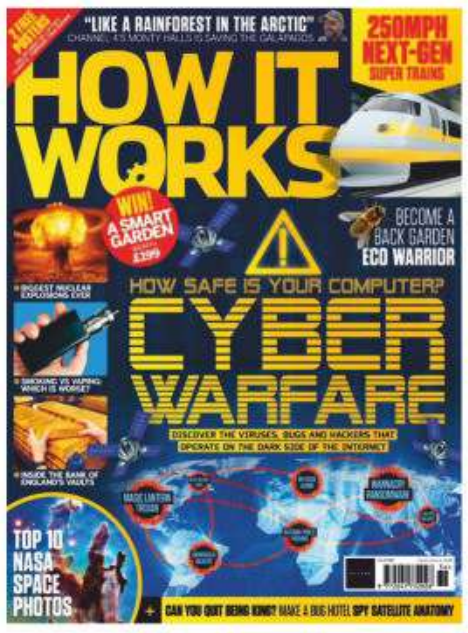

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"The potential damage this deadly cocktail can cause is vast"

Often believed to be a modern-day vice, smoking and chewing tobacco leaves have been habits humans have had for thousands of years. It wasn't until the early 1500s that tobacco cultivation reached Europe, after Christopher Columbus discovered Native Americans smoking dried tobacco leaves. By the 1700s smoking became widespread, resulting in the rise of the tobacco industry. Although it's been on a steady decline in recent years, in 2018 it was found that around 7.2 million people aged 18 and over smoked in the UK alone.

SMOKING VERSUS VAPING

WHY VAPING COULD BE JUST AS BAD FOR YOUR HEALTH AS CIGARETTE SMOKING

Words by **Scott Dutfield**

Invented as a way to curb the craving of cigarettes, vaping has quickly become the trend as a smoking alternative and a completely new vice. Creeping into the commercial market in the early 2000s, the first e-cigarettes were invented by Chinese pharmacist Hon Lik after his father, a heavy smoker, died from lung cancer. Marketed as a way to ditch the bad habit of smoking and a 'healthier' way to get a nicotine hit, the number of vapers has shot up to a whopping 41 million people globally in 2018, with researchers predicting a further climb to 55 million by 2021.

Currently around 17 per cent of men in the UK are smokers, whereas women smokers account for 13 per cent of the population

SMOKING

How damaging can a single cigarette be?

In 2017 the NHS found that 77,800 deaths were attributed to smoking, with a further 489,300 people admitted to hospital. As an efficient drug-delivery system, cigarettes are designed to facilitate the transport of addictive and dopamine-inducing chemicals such as nicotine into the smoker's bloodstream. For example, the average smoker inhales between one to two milligrams of nicotine per cigarette. Nicotine is the driving force of smoking addiction, with smokers pursuing an apparently stress-relieving shot of dopamine. With the average person taking ten puffs on a cigarette before it's burnt out, a single pack of 20 cigarettes will provide about 200 hits of nicotine.

Other than the addictive nature of nicotine, a single cigarette contains over 7,000 chemicals, of which at least 69 are known to cause cancer. One particularly destructive toxin is a residue called tar. Upon inhaling the smoke of burning tobacco, this brown sludge enters the lungs, coating the lining of the organ along with the walls of the trachea. Along these internal walls are tiny hair-like cells called cilia which are responsible for trapping pollutants and dust before they're absorbed by the body. As the tar builds, these cellular bodyguards become paralysed and unable to repel any unwanted intruders, leaving the body at risk of infection and opening a gateway to a collection of toxic chemicals. As the tar continues to accumulate, a once-healthy pink lung eventually becomes grey or black.

As one of the hundreds of smoke-bound toxins that can enter the body, the potential damage this deadly cocktail can cause is vast. Smoking causes 84 per cent of deaths from lung cancer and 83 per cent of deaths from chronic obstructive pulmonary disease. But the lungs aren't the only organ to be affected by smoking. In fact, nearly every aspect of the human body can be negatively impacted by smoking. From increasing blood pressure and greying skin to causing a stroke and infertility, as little as one cigarette a day is enough to increase a man's risk of developing heart disease by 48 per cent, and a 25 per cent higher risk of having a stroke.

The root of the problem

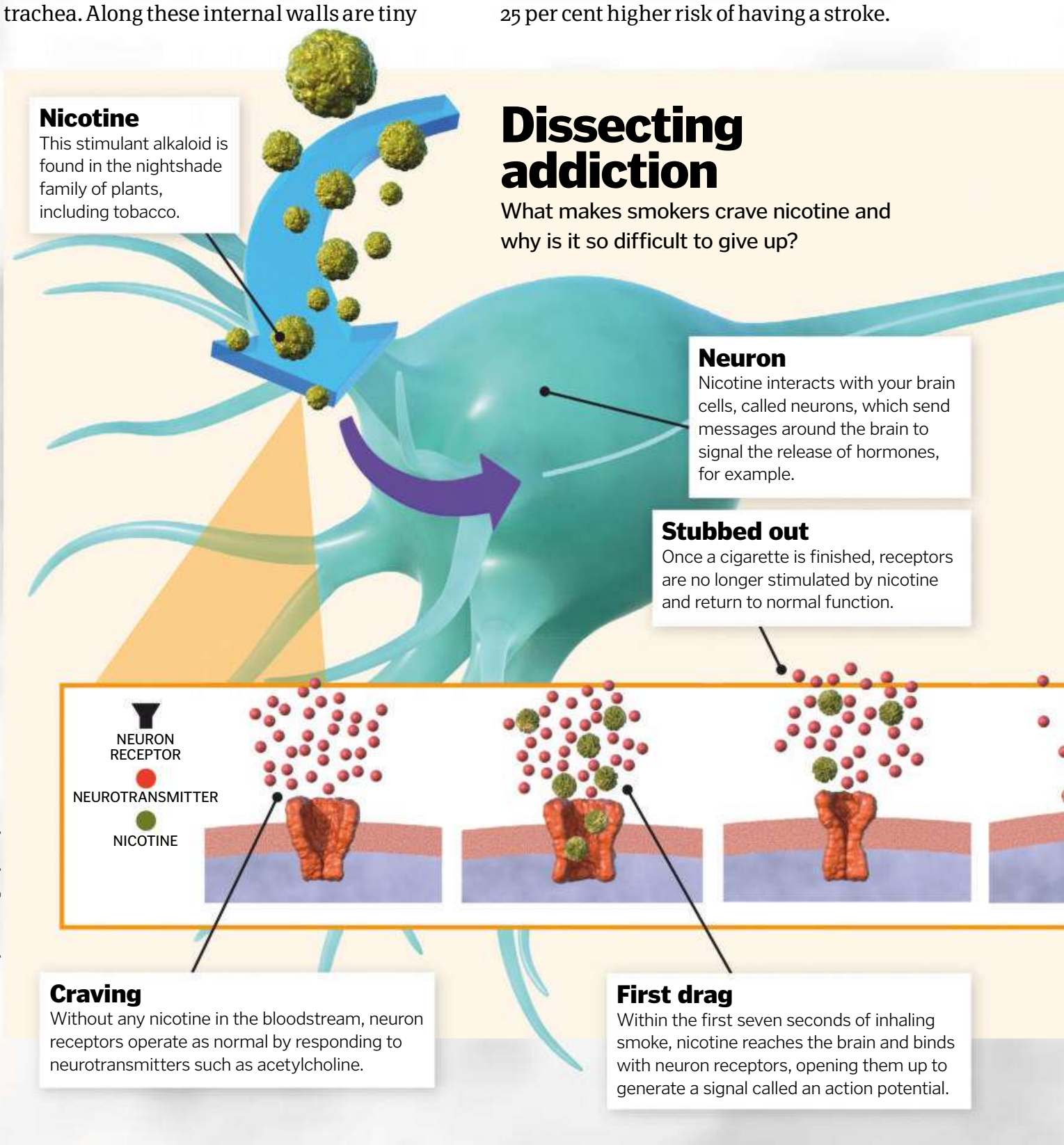
Tobacco (*Nicotiana tabacum*), native to both North and South America, is now one of the most cultivated plants around the world. China is the leading producer of tobacco, farming almost 2.3 million tonnes of the plant in 2017. Between the farmland and fingertips, harvested tobacco goes through different methods of curing and drying to create the tea-like filler found in cigarettes. For example, one method used in Virginia is flue-curing tobacco. This involves hanging picked leaves inside a small enclosed barn, which is heated by burning different woods and charcoal and vented. Curing transforms the once-lush green leaves into shrivelled yellow-brown dried leaves in four to eight days, ready to be processed and placed into cigarettes.

© Getty

Tobacco plants are grown in vast groves before heading to heated barns to dry out

Dissecting addiction

What makes smokers crave nicotine and why is it so difficult to give up?



Nicotine
This stimulant alkaloid is found in the nightshade family of plants, including tobacco.

Neuron
Nicotine interacts with your brain cells, called neurons, which send messages around the brain to signal the release of hormones, for example.

Stubbed out
Once a cigarette is finished, receptors are no longer stimulated by nicotine and return to normal function.

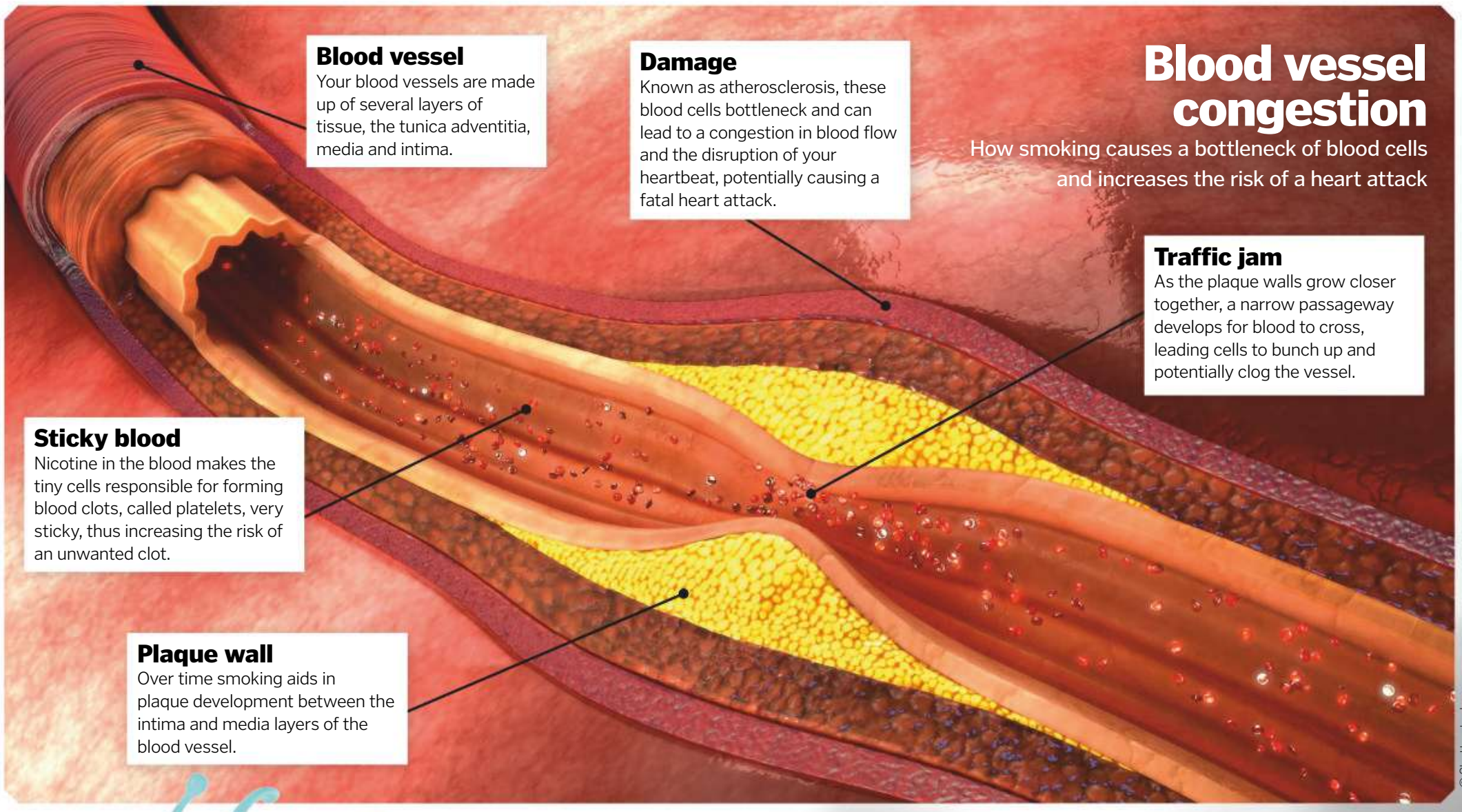
Craving
Without any nicotine in the bloodstream, neuron receptors operate as normal by responding to neurotransmitters such as acetylcholine.

First drag
Within the first seven seconds of inhaling smoke, nicotine reaches the brain and binds with neuron receptors, opening them up to generate a signal called an action potential.

© Illustration by The Art Agency/Barry Croucher

Blood vessel congestion

How smoking causes a bottleneck of blood cells and increases the risk of a heart attack



Blood vessel
Your blood vessels are made up of several layers of tissue, the tunica adventitia, media and intima.

Damage
Known as atherosclerosis, these blood cells bottleneck and can lead to a congestion in blood flow and the disruption of your heartbeat, potentially causing a fatal heart attack.

Traffic jam
As the plaque walls grow closer together, a narrow passageway develops for blood to cross, leading cells to bunch up and potentially clog the vessel.

Sticky blood
Nicotine in the blood makes the tiny cells responsible for forming blood clots, called platelets, very sticky, thus increasing the risk of an unwanted clot.

Plaque wall
Over time smoking aids in plaque development between the intima and media layers of the blood vessel.

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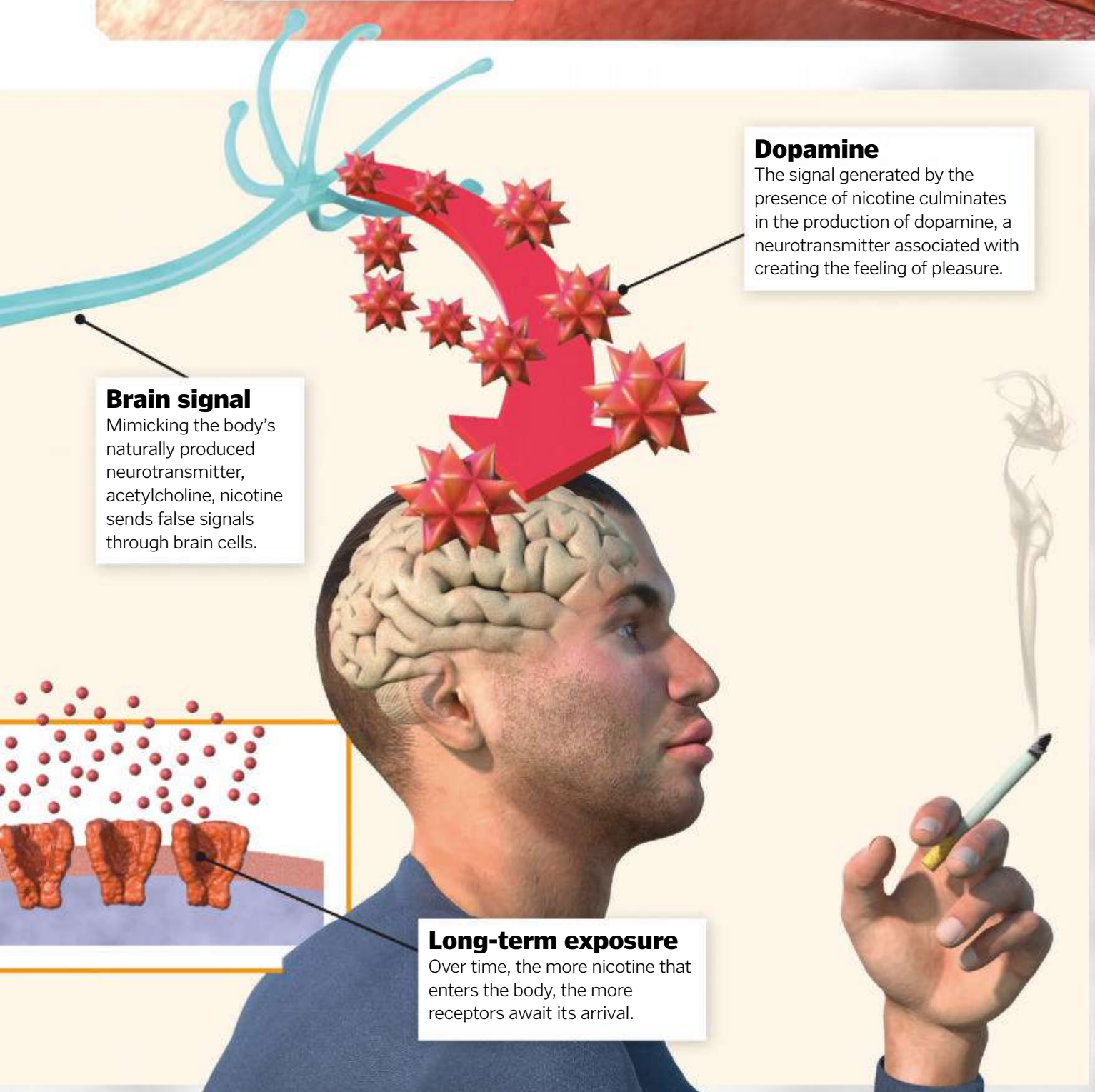

Dopamine
The signal generated by the presence of nicotine culminates in the production of dopamine, a neurotransmitter associated with creating the feeling of pleasure.

Brain signal
Mimicking the body's naturally produced neurotransmitter, acetylcholine, nicotine sends false signals through brain cells.

Long-term exposure
Over time, the more nicotine that enters the body, the more receptors await its arrival.

Do cigarette filters work?

Before the 1950s cigarettes were smoked without the use of a barrier between leaf and lips. However, as concerns began to grow about the potentially damaging effects of lighting up, the production of cigarette filters began. Manufacturers promised spongy plastic cellulose-acetate filters were a way to remove the majority of smoke – and thus the dangerous tar and nicotine – from entering the body. This was believed to be due to the perforations within the filter allowing more air through and less smoke. However, once addicted the body craves a certain amount of nicotine: filters reduce the amount of nicotine inhaled, which means that smokers turn to light another cigarette until they can satisfy their craving.

© Getty

Cigarette filters have accounted for around 40 per cent of all litter found in coastal regions

© Alamy

VAPING

Is vaping the answer to quitting smoking, or does it cause more problems than it solves?

Created as a way to help prevent the devastating effects of smoking, over the past few years vaping has been found to be the cause of its own set of illnesses.

Quitting smoking, along with any addiction, can be incredibly challenging due to the body's dependence on the chemical compound nicotine. Replacement products such as nicotine patches, lozenges and gum offer an alternative way to get a nicotine fix without inhaling the thousands of chemicals that come with each lit cigarette. However, where these products have fallen short is their lack of ability to address the behavioural aspect of smoking.

Introducing the electronic cigarette, or 'vape': promising the same dopamine rush gained from a tobacco cigarette and mimicking the oral habit of smoking, e-cigarettes have quickly become the digital answer for treating addiction… but at what cost?

The billowing clouds of false smoke that pour from the mouths of vape smokers are a result of liquid vaporisation or atomisation. While inhaling through a mouthpiece of an e-cigarette, a drop of nicotine-rich fluid, commonly called 'e-liquid', is heated and quickly converted into a vapour. The vapour carries all the nicotine a smoker craves, delivering it in the same way as cigarette smoke when it enters the lungs and diffuses into cauliflower-like cavities called alveoli. Although the dangers of inhaling nicotine remain, another collection of conditions have been brought to light that are linked with vaping.

"E-cigarettes have quickly become the digital answer for treating addiction… but at what cost?"

After increasing levels of unexplained respiratory issues began to pile up in patients in recent years, medical attention turned to vaping. Over time, an increasing number of otherwise healthy individuals who vaped were being rushed into hospital with symptoms such as shortness of breath, fever, coughs and chest pain. Now known as 'e-cigarette or vaping product use-associated lung injury' (EVALI), it's believed that damage to the lungs as a result of vaping points to a THC (a cannabinoid from the marijuana plant) additive. However, research into the cause of EVALI is still in its infancy, with much more research needed to fully understand the condition. As of 18 February 2020, the Centers for Disease Control and Prevention confirmed 68 deaths in patients with EVALI.

DID YOU KNOW? *Estimates suggest that the global vaping industry will be worth $53 billion (about £40 billion) by 2024*

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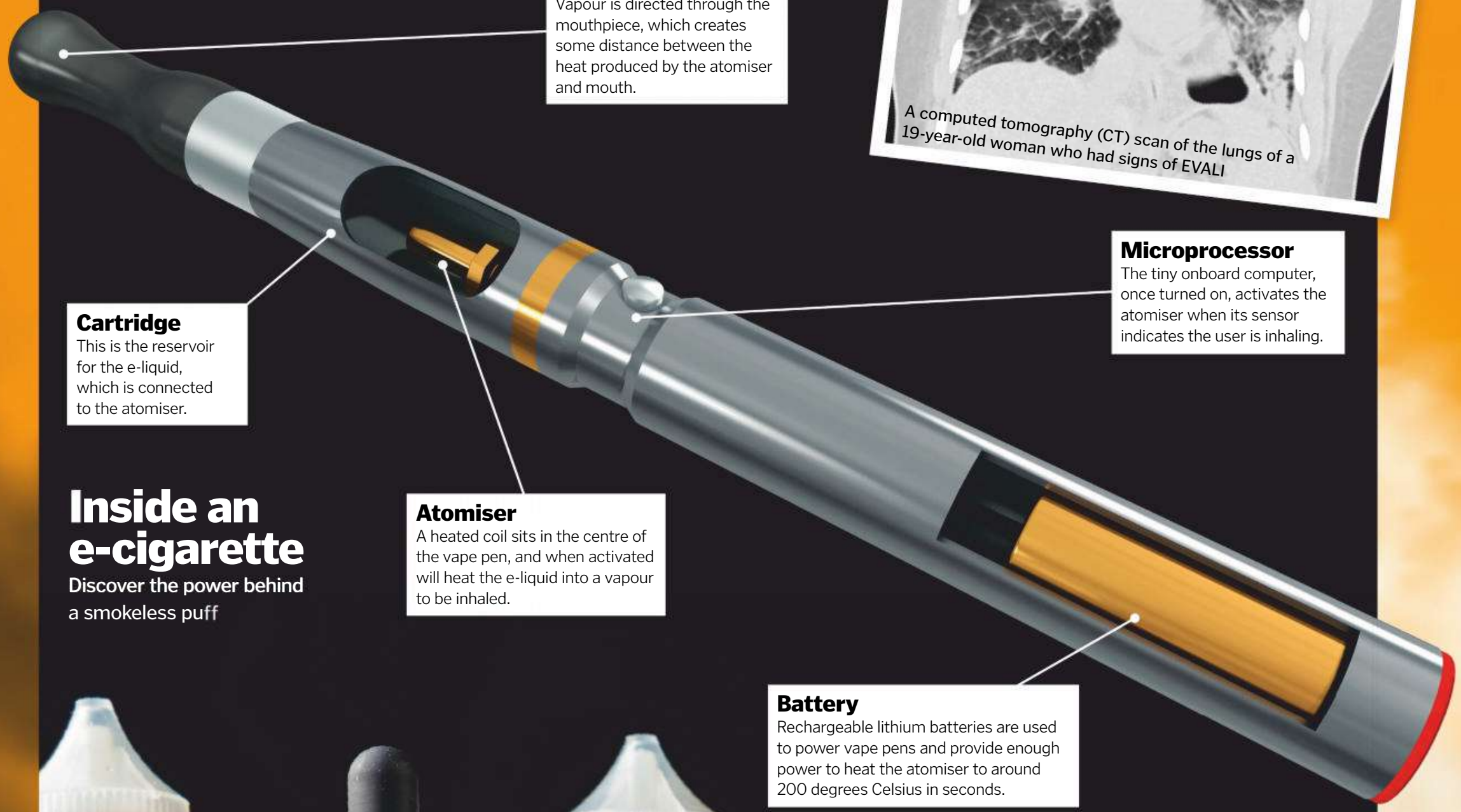


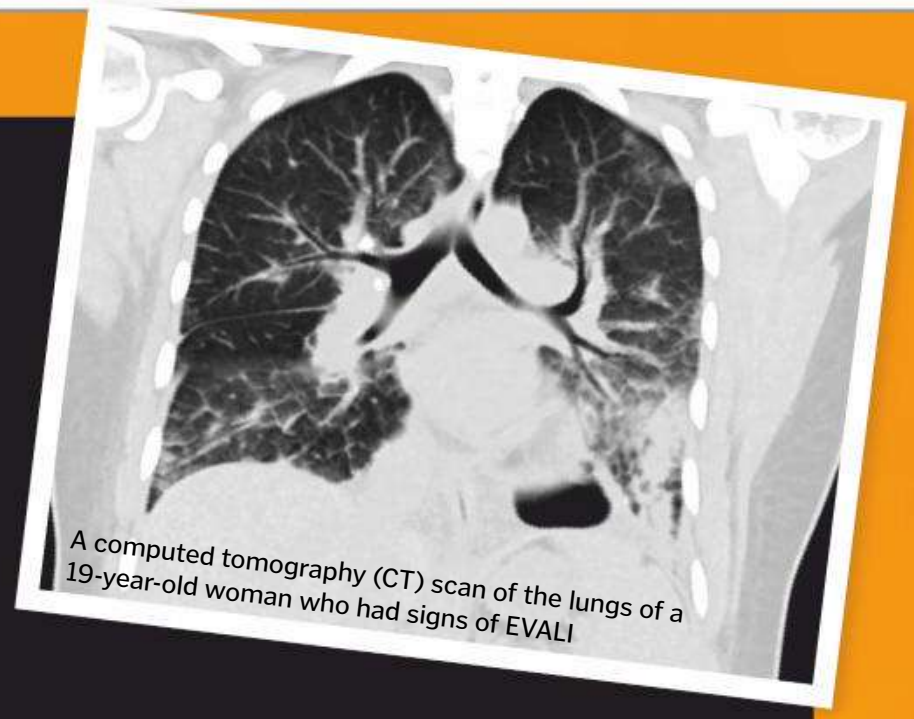
Mouthpiece
Vapour is directed through the mouthpiece, which creates some distance between the heat produced by the atomiser and mouth.

Cartridge
This is the reservoir for the e-liquid, which is connected to the atomiser.

Atomiser
A heated coil sits in the centre of the vape pen, and when activated will heat the e-liquid into a vapour to be inhaled.

Microprocessor
The tiny onboard computer, once turned on, activates the atomiser when its sensor indicates the user is inhaling.

Battery
Rechargeable lithium batteries are used to power vape pens and provide enough power to heat the atomiser to around 200 degrees Celsius in seconds.



A computed tomography (CT) scan of the lungs of a 19-year-old woman who had signs of EVALI

Inside an e-cigarette

Discover the power behind a smokeless puff

Flavouring smoke

From natural flavours such as cinnamon and vanilla to the artificial tastes of bubblegum, Red Bull and even hot dogs, the vaping industry has created a seemingly endless list of potential vaping flavours. But how are flavours made? The answer lies in the chemical composition of the e-liquid which is vaporised within the e-cigarette. Similar to the production of essences added to food, chemicals such as ethyl vanillin (vanilla) and cinnamaldehyde (cinnamon) are added to propylene glycol or vegetable glycerin – a sugar alcohol product derived from animal products, plants or petroleum – and nicotine. This chemical cocktail is then transformed into a vapour when heated to around 200 degrees Celsius, carrying the flavour chemicals along in the cloud of vapour.

© Alamy

How meat is cured

Why do cured meats have such a long shelf life?

Curing meat keeps it safe for consumption over a prolonged period of time. Using a combination of methods in production, the qualities of meat are manipulated to make it more difficult for microbes to invade. When these processes were first established, they held the single purpose of preventing the spread of disease, especially in populated areas. However, with the emergence of fridges and freezers, some of these early methods are simply used for the sake of tradition, or to add to the flavour using salt, herbs and spices.

Over 200 diseases are transmitted through food. The most common bacteria in beef is *E.coli*

© Getty

Methods

© Alamy

Salting

Short-term

Salt acts as a natural anti-bacterial agent by preventing bacterial enzymes from working and destroying DNA, making it difficult for bacteria to grow on salty meats. The salt also works to dehydrate the meat, removing some of the water that bacteria need to thrive. For dry salt curing, it needs to be rubbed into the meat by hand.

© Alamy

Brining

Short-term

A concentration of at least 20 per cent salt in water makes a salt brine. As the salty concentration sits on the outside of the meat, it draws water out of microorganisms' cells. The salt also replaces some of the lost water within the meat. This ensures that the salt helps prevent the growth of bacteria throughout.

© Getty

Nitrate and nitrite

Long-term

Using nitrates and nitrites in meat curing helps to maintain the meat's red colour, while also killing harmful microbes. However, when nitrites are cooked with the amino acids of meat at high temperatures, they can form toxic compounds. Nitrosamine is a cancer-causing chemical that can result from this process.

© Alamy

Drying

Long-term

Dehydrating meat not only preserves it, but also makes it more compact. If kept in a freezer, its freshness can be maintained for six months. One example of dried meat is beef jerky. Jerky is dried meat where 50 per cent of the water has been taken out. After bones and fat are removed, meat is placed in drying ovens for 12 hours.

© Getty

Canning

Long-term

Three main steps in meat canning include filling the can, exhaustion and heat treatment. When filling, around 30 per cent of the can is brine. Air exhaustion removes all air and reduces the ability of aerobic bacteria to live inside. After heating to around 90 degrees Celsius, the cans are sealed. This produces a vacuum when the can cools.

Meat curing in the Middle Ages

Meat curing is a method that has been used for centuries. Food preservation in the Middle Ages, for example, was essential to life, whether it was preserving fruits in the summer to last the harsh winters, or slaughtering and storing their animals so they wouldn't need to feed them over winter.

Every year before winter, families would prepare a bathtub of salt water, which they would use to keep fresh meat and fish in. When cooked, meat was often coated in gelatine to preserve it, while pork was often smoked over a fire.

Looking further back, cave paintings discovered in Sicily from 40,000 BCE give us reason to believe people used to use salt from seawater evaporation and ash from plants to cure early meats.

© Getty

Medieval meat curing involved hanging meat in smoke houses like this

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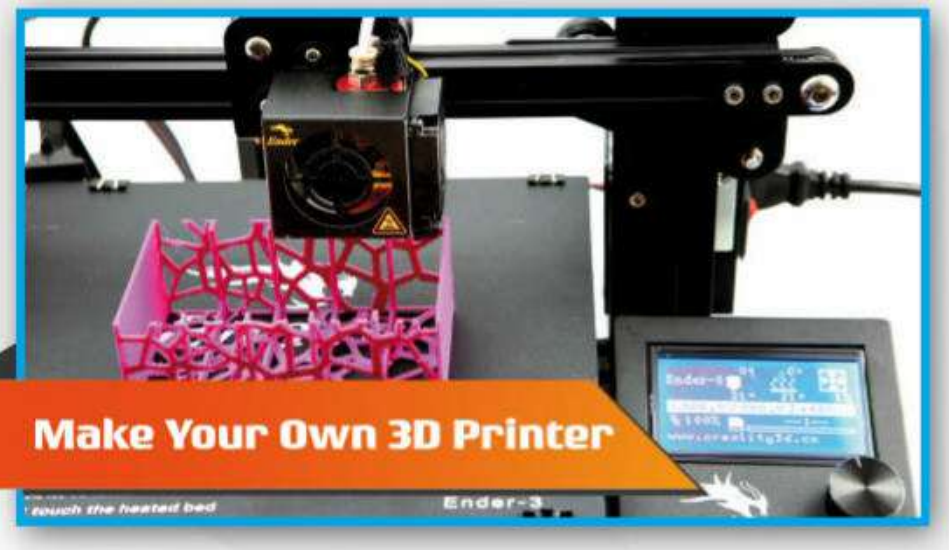

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BECOME A back garden eco-warrior

Believe it or not, you can help save the planet without leaving your own home

Words by **Joanna Elphick**

Leading scientists, environmentalists and governments the world over are trying to save the Earth from a horrifying future, a future without orangutans swinging through the rainforest or Amur leopards padding across the snowy Russian mountains. The thought of losing our gorillas, sea turtles and rhinos is truly terrifying, but if you think that saving our planet is a job for hugely influential individuals, then it's time to think again, because pint-sized eco-warriors the world over are beginning to make a difference… and so could you.

While people tend to think of large animals needing our help, we should also consider the under-appreciated insects that break down and dispose of the world's waste. They pollinate our plants, keep pests in check and provide us with extremely useful products such as beeswax and silk. Sadly, the vast majority of species teetering on the verge of extinction are insects. Birds too, once considered commonplace, are in rapid decline and hurtling towards extinction. It's high time to act.

Although it's unlikely you possess your own piece of rainforest or coral reef, many people have access to a back garden. With some quick, clever changes, you can make a welcoming home for your native wildlife. Becoming a back garden eco-warrior isn't as simple as weeding the flower beds and watering the plants. It requires gardeners to reduce their waste, reuse where possible and make smart choices.

© Getty

A bug house will encourage a variety of insects into your garden

© Getty

You never know who might visit your eco-friendly garden

By avoiding synthetic fertilisers and insecticides, gardeners can reduce carbon dioxide emissions created during their production process. Rather than poisoning pests, it is easy to deter unwanted visitors by planting certain herbs and flowers in and around your fruit and vegetable crops. Chives, basil and garlic will keep the pests at bay and can be used in cooking too, so nothing goes to waste and the soil remains uncontaminated.

Take a look at the flowers in your garden. Are they covered in bees and butterflies? If the answer is no, then you have failed to encourage precious pollinators onto your land. There are so many beautiful plants that will brighten your garden and feed insects, so make a conscious decision to choose nectar plants. If you have a small plot of land, why not plant some wildflowers and make a mini meadow. Over 40 species of grasses and flowers can thrive on one square metre of meadowland compared to a turfed lawn of the same size. You could entice hedgehogs and other small mammals by piling up some logs or leaving the grass clippings in a heap over winter. Strange as it may seem, you can help the planet by doing less. A tidy garden will not seem appealing, but a few nettles and weeds, an upturned plant pot or fallen fruit will soon have your outside space teeming with wildlife.

If you are short of space or don't have access to a garden you can still help by creating a window box and an accompanying bug hotel. By planting bee- and butterfly-friendly flowers you can attract the pollinators, then get them to stay by offering them a warm and cosy home to live in. Insects need somewhere safe to hide from predators and shelter from bad weather. A bug hotel will make the perfect retreat, and the good news is it won't cost a penny. Build your bug house out of reclaimed materials such as broken pots, fallen wood, pine cones and old pipes. Just make sure that there are lots of different sized nooks and crannies for your guests to crawl into. Before you know it you will be supporting your native wildlife – and the planet.

"Eco-warriors the world over are beginning to make a difference"

© Getty

A perfectly prim garden might not be the most attractive to critters

Super bees: the perfect pollinators

With 20,000 different species buzzing around the Earth, the humble bee is one of the most invaluable living things on our planet. They have been providing us with honey for thousands of years and pollinating our flowers, quite rightly becoming the ultimate garden hero, but people don't realise that a world without bees would bring about the end of human civilisation. Over 90 per cent of all major global crop types are pollinated by these industrious insects, creating vegetables, nuts and fruits, with bees ultimately becoming responsible for over one-third of our daily diet. Without them we would simply starve.

Sadly, a combination of overuse of pesticides, climate change and loss of habitat has caused a worldwide decline in bees. By planting beebalms and foxgloves in your garden and letting ivy grow up the walls, you will be helping the bees who spend so much time helping us.

© Getty

Bumblebees collect pollen from all sorts of flowers, including wild daisies

NATURAL pest control

Meet mother nature's bug heroes, the plants that will attract them into your garden and the insect villains they prey upon

HERO

© Getty

Ladybird

This beautiful and well-loved beetle will eat many unwanted pests including aphids, mites, fleas and whitefly. When threatened they warn predators by exuding a bitter, pungent fluid.

ATTRACTED BY

Dandelions, common yarrow and dill will all encourage ladybirds into your garden.

© Getty

Ground beetles

Night-active ground beetles can be found all over the world and include over 40,000 species. They are popular with gardeners since they prey upon unwanted slugs, caterpillars and cutworms.

ATTRACTED BY

Planting clover, evening primrose and Amaranthus will attract these heroes.

© Getty

Spiders

Although often unpopular, spiders will get rid of many garden villains including fruit flies, aphids and mosquitoes. There are over 45,000 species of spider worldwide, keeping fly infestations to a minimum.

ATTRACTED BY

Any tall plants or thick bushes.

© Alamy

Damsel bugs

Damsel bugs prey upon aphids, mites, caterpillars, potato beetles and many other crop pests, catching hold of insects with their long forelegs.

ATTRACTED BY

Sweet-smelling spearmint, fennel and caraway will encourage damsel bugs onto your property.

© Getty

Hoverflies

The adult hoverfly is a useful pollinator since it enjoys sipping nectar, while its larvae will prey upon aphids, scale insects and caterpillars. They are therefore particularly popular with agricultural farmers.

ATTRACTED BY

Yarrow, dill and statice.

VILLAIN

© Getty

Aphids

Aphids target soft new growth and secrete sticky honeydew which creates the growth of mould. They multiply incredibly quickly and can overrun a plant within a day.

EATEN BY

Damsel bugs, ladybirds, lacewing, hover flies, beetles, midges

© Getty

Fleas

Fleas are universally disliked by everyone, not just gardeners, since they bite both humans and pets. Planting pennyroyal in the garden and by the back door deters fleas from settling.

EATEN BY

Snakes, ants, beetles, frogs, lizards

© Alamy

Cabbage worm caterpillar

They eat through many varieties of vegetables before spinning a cocoon and attaching to a plant where they pupate. They re-emerge as butterflies and lay eggs, starting the cycle again.

EATEN BY

Wasps, shield bugs, birds

© Alamy

Mealybugs

Mealybugs are soft pink, grey or white insects that suck tender stems. They are particularly keen on delicate plants that thrive in greenhouses.

EATEN BY

Lacewing, Mealybug ladybird, spiders

© Getty

Red spider mite

The minute spider mite sucks the chlorophyll from the leaves of plants such as the tomato plant, damaging the leaves and leaving a silky web behind.

EATEN BY

Ladybirds, predatory mites

Wildlife safari garden

Making your back garden wildlife-friendly needn't be expensive, time-consuming or difficult

The right flowers will attract all kinds of pollinators

© Getty

Bird B&B
Encourage birds onto your property with the promise of an easy meal and a place to nest.

Cosy climbers
Honeysuckle will attract the pollinators and acts as a roost site for nesting birds.

Secret entrances
Tiny gaps under your fence will allow small mammals to enter and exit, such as hedgehogs and frogs.

An urban watering hole
A pond will encourage many creatures into your garden and also help to absorb noxious carbon dioxide out of the air.

Insect caves
Stony nooks and crannies provide homes for insects and little bridges for creatures to safely reach the water.

Trees
By planting trees in an urban garden, you are improving the purity of the surrounding air and providing shade and shelter.

An untidy shed
A ramshackle shed will provide a perfect home for spiders, mice and earwigs, sheltering from the rain.

A not-so-neat-and-tidy lawn
Lawn weeds such as clover and dandelions provide vital pollen for the bees, so avoid cutting your lawn too short.

Beware of the pet!
Ensure that your pets wear bells on their collars to warn the wildlife of their arrival into the garden.

A crazy-paving path
Allows wildflowers to self-seed in the cracks and provides dark nooks for woodlice to thrive in.

© Illustration by The Art Agency / Peter Scott

A gardener's black gold

Compost comprises of decomposed organic matter such as twigs, clippings and kitchen scraps. It is estimated that between 10 and 30 per cent of landfills are made up of garden and household waste that could have been used to make this environmentally friendly resource. Compost can be used as a fertiliser, reintroducing vital nutrients and 'humus' during the planting of delicate seedlings and saplings. It can also be used to combat areas of high erosion. The compost is added to topsoil to stop sediment run-off and control the impact of rainfall.

Making your own compost is easy and inexpensive. Select your container, remove the bottom so that its contents touch the soil and ventilate the sides. Use small branches at the base to aerate the pile. Make a layer of green materials such as fresh grass clippings, which will provide nitrogen, and a brown layer including dea leaves which will provide carbon. Water the pile if it gets too dry and aerate by mixing the heap.

© Illustration by The Art Agency / Nick Sellers

Protective cover
Stops water from entering and keeps heat in.

Rising air
Compost heaps get hot, causing air to rise.

Circulating air
Small gaps in the walls aerate the compost.

Inside the heap
Microorganisms break down organic material.

Life on a volcanic island

Monty Halls tells us about his time on the wild Galápagos archipelago

We caught up with broadcaster, marine biologist and former Royal Marine, Monty Halls, to talk about his experiences with his family on the Galápagos Islands, for his new Channel 4 documentary series and his book. *My Family and the Galapagos* follows Monty, his wife Tam and their two children Isla and Molly as they explore the islands, discover the resident wildlife and uncover the negative impacts human populations – both on the islands and globally – are having on its ecosystem.

How has the Galápagos changed since the first series of *My Family and the Galapagos*?
The change has been quite rapid over the last few years; it was notable during that two-year period, just the volume of people. It was really as simple as that. When I visited the last time it was about 220 to 230,000 people. This time there were 275,000 people visiting the islands. With that comes a lot of money and a lot of infrastructure, and there is a sort of confidence in the island. Certainly, in terms of the main town there, you could tell there was a bit of money there, and a bit of affluence, which wasn't there a couple of years ago. This is the positive side for the local population and creates a viable income to support the population there. However, on the negative side is the impact of that volume of people. Both Tam and I commented on it. You can see it in the queues at the cash points and all the restaurants were full. The island is certainly open for business.

What effect will this population growth have on the islands' ecosystem?
Without a doubt the effect is negative, and the ongoing challenge the islands face is how to deal with this influx and whether the influx should be curtailed. They set limits every year for the islands and every year those limits are surpassed and surpassed again, so it's a tricky one. Also, who are we to say, in the western world, "no you've got to stop now," because tourists want to come and look at iguanas and a World Heritage Site. Whereas actually, the local people are saying, "this is our income, this is our living. Who are you to tell us we can't do it." But what is undeniable and a stark truth is that there are too many people visiting the Galápagos at the moment, and it will have an impact on the ecosystem there. It's definitely a problem that needs to be managed.

What are the wider challenges that the islands are facing?
The islands have always been a microcosm of the wider world. For example, climate change is undeniably having an impact. The frequency and severity of El Niño events, where you get this very dramatic increase in water temperature, means the food animals like penguins and iguanas eat such as small fish are driven offshore, which leads to penguin deaths in droves, or the algae doesn't grow because the temperature differential is too great, so the iguanas die. Ocean acidification undeniably has an impact, and other elements such as invasive species. The more we travel around the world and the more infrastructure that grows around the world, you end up with species being transferred from place to place. That can have a very negative impact. For example, there's a plant called the hill raspberry, which is having a devastating impact on the fauna and flora out there.

In the first episode, you address the problem of plastic on the islands. How apparent was this issue during your time there?
Without a doubt plastic is absolutely everywhere in the world. It just goes to show there is nowhere that is unaffected. The Galápagos is a part of Pacific gyre, so there is a mass movement of water and currents that bring plastic debris from the Pacific from Asia. The time you really notice it on the islands are within mangrove areas. Their roots catch loads as they sieve the water and you'll see them full of plastic. But again, measures are being taken such as straws bans on the islands, along with plastic bags.

Were there any moments that took your breath away or surprised you?
I've been very lucky to have worked in the

There are too many people visiting the Galápagos, and it will have an impact

Galápagos and had some great encounters around the world. But I've never done it with my kids, so the part that really blew me away was taking Isla and Molly into the water for their first snorkelling experience. A green turtle came up to say hello and they saw stingrays and sharks. Those moments you can't put a price on. I got the opportunity to take my little ones into the water and introduce them to a whole new world. I think for me they were the really big moments that you can almost see the transformation. You can almost see when they come out of the water, they're like, right, I know exactly what I'm doing for the rest of my life.

The Galápagos had always had a delicate yet blossoming ecosystem. How have the islands maintained their diversity?

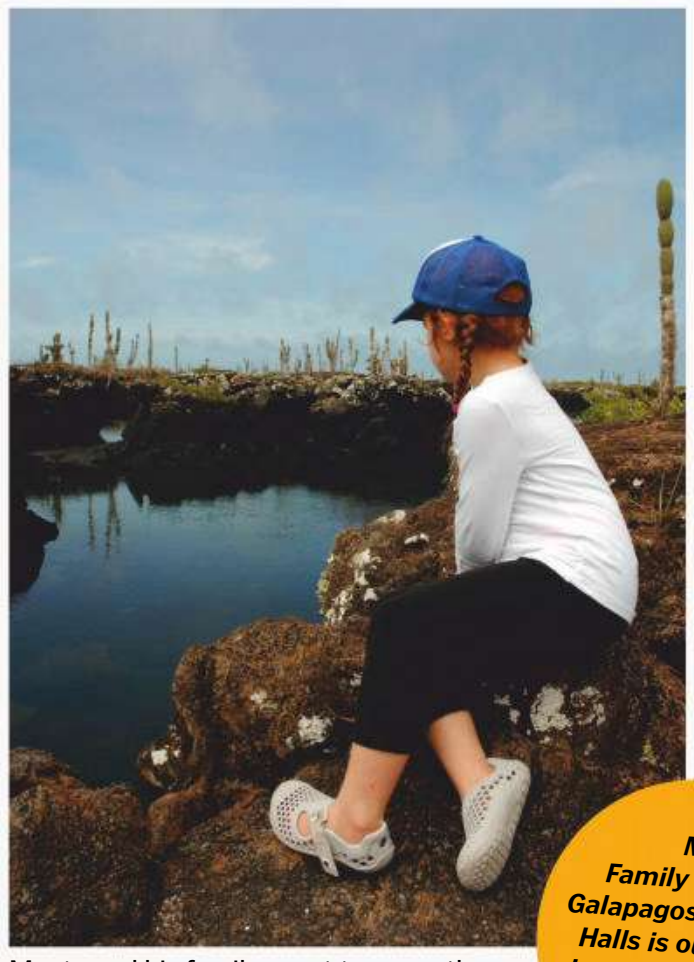
That's a very interesting point. 95 per cent of species diversity on the islands is the same as when man first set foot on the islands in 1535. There's no other island group on Earth that has that statistic. It's such an incredibly difficult place to live for people. You're 600 miles offshore, you're bang on the equator, aside from in the highlands, and it's so difficult to grow anything. It's difficult to get things out there and so people haven't really colonised it in any meaningful way. There are loads of places around the islands that people just couldn't get to. Those are the places where the animals have retreated to. If you take Isabela Island, for example, a tiny little part of it is where people live, and the rest of the island is just taken over by animals because it's too inhospitable for us. Also, 98 per cent of the whole island area is a National Park, so it's been pretty well looked after up to this point.

The islands have been studied for centuries; is there much more to discover there, in the sea or on land?

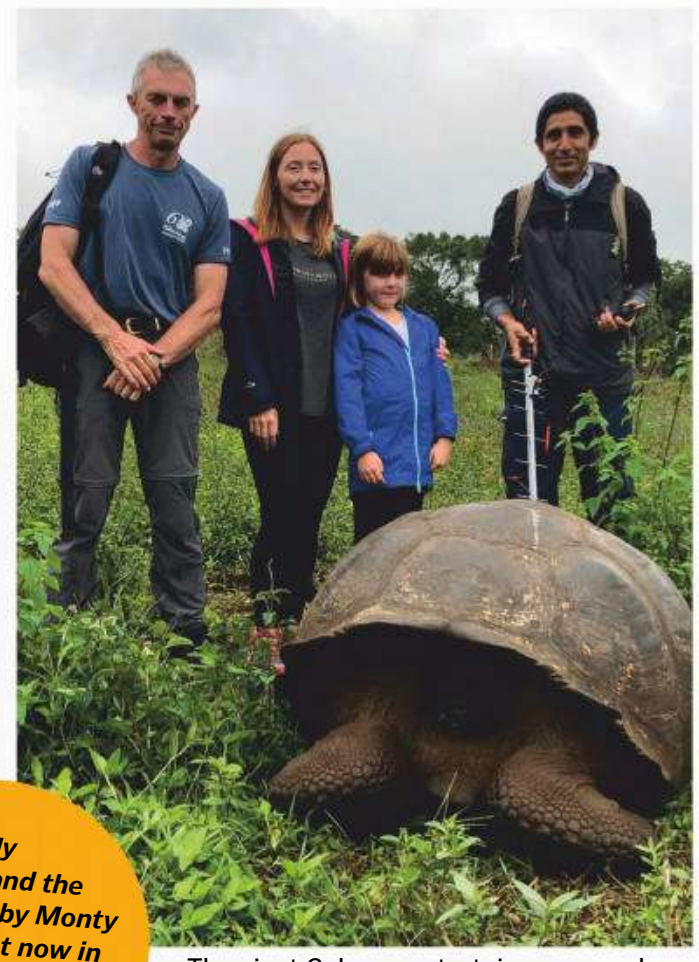
Yeah – you'll see it right at the end of the series. We did an incredible dive with a group of young female scientists, on top of the seamount which had a kelp bed on it. Kelp beds on the equator and in the tropics are unheard of. The Galápagos has a cold upwelling and it's made this kelp bed thrive. It's like finding a rainforest in the Arctic; it's amazing. In the ocean there's a species of sunfish that we think is specific to the Galápagos and giant manta rays that we think may be a subspecies. And again on land, we're just learning about things like rat eradication, and rewilding, which can be a template for all sorts of places around the world. The Galápagos remains this laboratory and a lens through which we can view the rest of the world. It's the tip-of-the-iceberg stuff with much more to learn from the islands.

www.howitworksdaily.com

Halls' daughters Isla and Molly experienced the underwater ecosystem on their first snorkel



Monty and his family spent two months exploring the islands' wildlife



The giant Galapagos tortoise can reach up to 400 kilograms in weight

My Family and the Galapagos by Monty Halls is out now in hardback, priced at £20 / $23.95 (Headline)

Monty discovered that marine iguanas can shrink their skeletons by 20 per cent when food is scarce

All images © Channel 4

How worms dig

These fleshy creatures perform an impressive physical feat to wiggle their limbless bodies through the soil

Words by **Ailsa Harvey**

As the soft, squishy, pink things you first encounter when you're playing outside as a kid, worms appear extremely fragile. With a soft outer skin and little protection, when you first saw them bury themselves out of sight and into the ground you may have wondered how they managed it. And how can they possibly navigate these depths without any eyes or ears? When worms dig they are moving a stream of soil. Consuming the loam as they roam, this soil passes through their elongated bodies before being excreted behind them in their wake. Digesting organic matter and leaves as food, they also return nutrients to the soil as they travel.

In a world of darkness, the only method they have to survive the continuous threats of bird beaks, hungry moles and other predators is to feel their way through. Nerves in their bodies can detect light and vibrations as they manoeuvre, and their bodies move in response. We only get to see worms' movements for a small fraction of their lives on the odd occasion they surface, so what magic are they working when out of sight and in their element?

© Getty

Worms usually stay a few centimetres below ground, but this depends on how waterlogged the ground is

Soil saviours

Worms benefit soil just by burrowing through it, providing nutrients and ensuring oxygen reaches deeper underground. Travelling in all directions through the ground, earthworms produce pores and gaps in the soil. These act as ventilation and create access for both oxygen and water.

With deep vertical tunnels being constructed in soil plentiful with worm life, a natural drainage system is created. Allowing for the quick escape of water through these burrows ensures that water has somewhere to go and prevents the likelihood of a damaging flash flood.

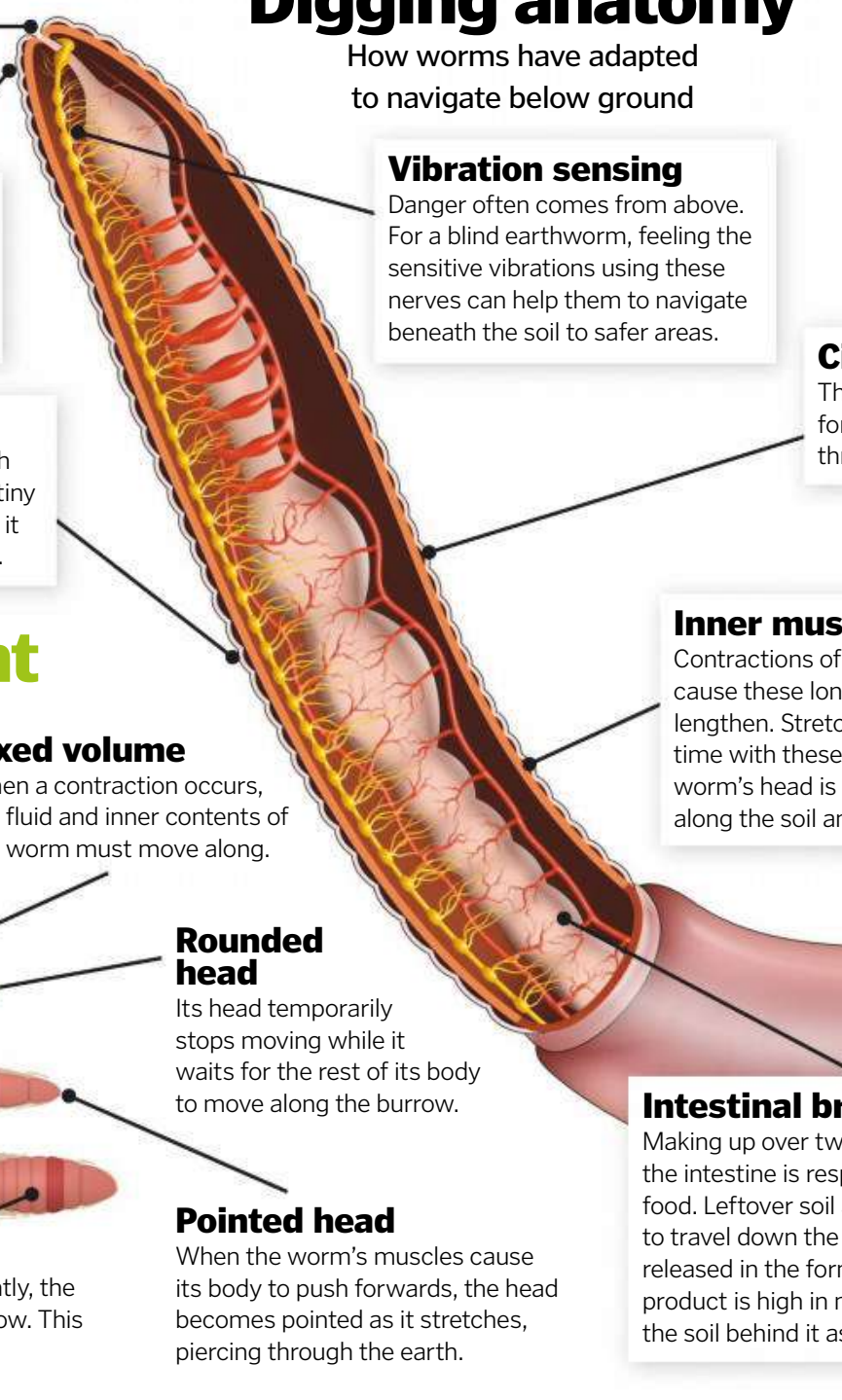
The nourishing nutrients worms release into the earth include nitrogen, phosphorus, potassium and calcium. These are essential for the healthy growth of crops. As worms populate the soil, they spread a range of bacteria from their insides as well as increasing the volume of fungi and mucus.

© Getty

In some areas, earthworms contribute 28 per cent of carbon found in the soil

Digging anatomy

How worms have adapted to navigate below ground



Muscular mouths
Worms' mouths are so strong they can use them to pull leaves into the ground.

Streamlined head
The head is pointed, helping them push through soil. This end of their body is also slightly firmer, which helps to move the earth aside as they push through small crevices.

Hairy grips
To ensure that the worm doesn't stretch in both directions at the same time, moving nowhere, tiny hairs called setae attach to the soil. These take it in turns to grip the soil from the front and back.

Vibration sensing
Danger often comes from above. For a blind earthworm, feeling the sensitive vibrations using these nerves can help them to navigate beneath the soil to safer areas.

Circular muscles
These outer muscles are responsible for initiating the worm's movement through the earth, by contrating.

Inner muscles
Contractions of the outer body cause these longitudinal muscles to lengthen. Stretching and shrinking in time with these contractions, the worm's head is able to move further along the soil and the tail follows.

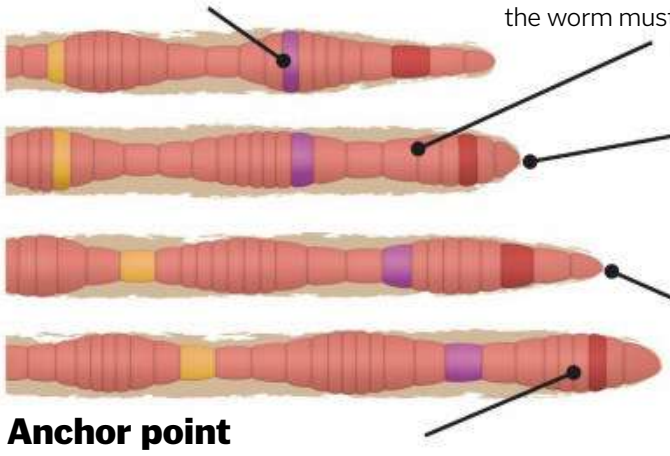
Intestinal breakdown
Making up over two-thirds of the worm's body, the intestine is responsible for breaking down food. Leftover soil and organic matter continue to travel down the length of the worm and are released in the form of castings. This waste product is high in nutrients and helps fertilise the soil behind it as it moves.

© Shutterstock

Worm movement

Width control
Using contractions, these circular muscles cause the inner muscles to move in opposition.

Fixed volume
When a contraction occurs, the fluid and inner contents of the worm must move along.



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Rounded head
Its head temporarily stops moving while it waits for the rest of its body to move along the burrow.

Pointed head
When the worm's muscles cause its body to push forwards, the head becomes pointed as it stretches, piercing through the earth.

Anchor point
With each muscle segment working independently, the thicker segments attach to the walls of the burrow. This prevents backwards movement.

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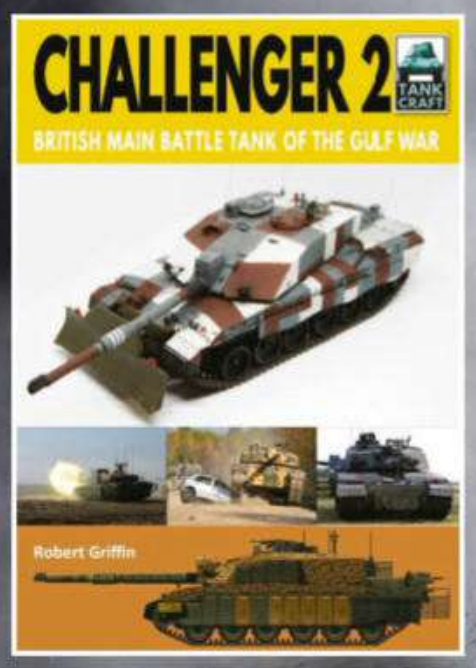

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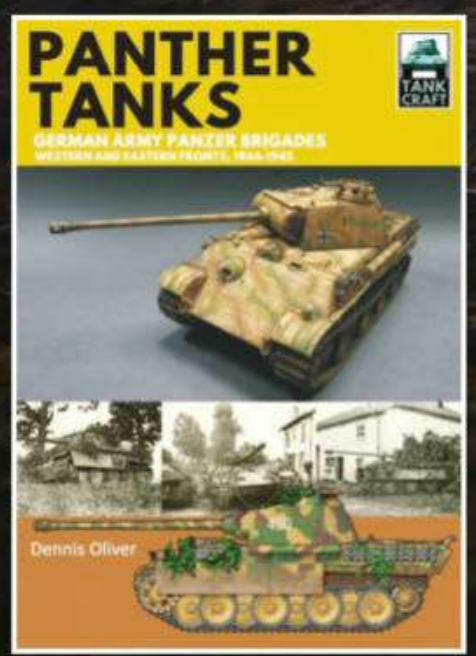

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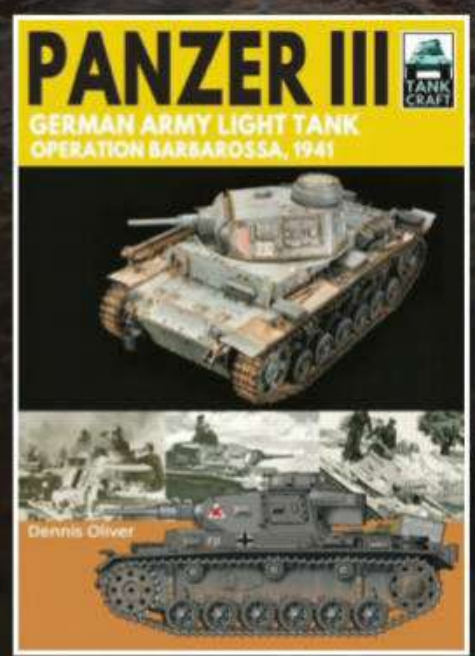

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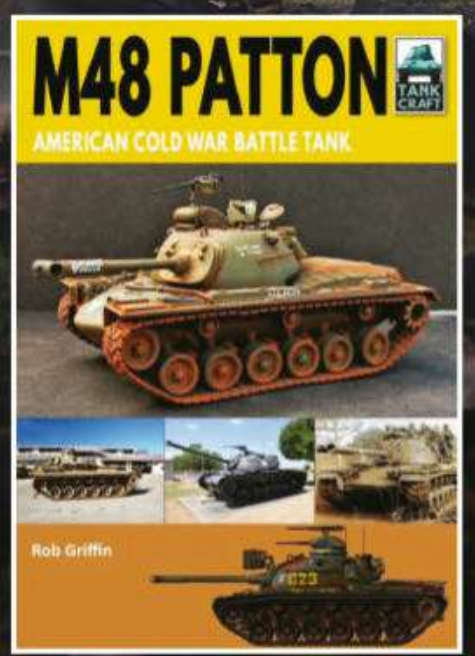

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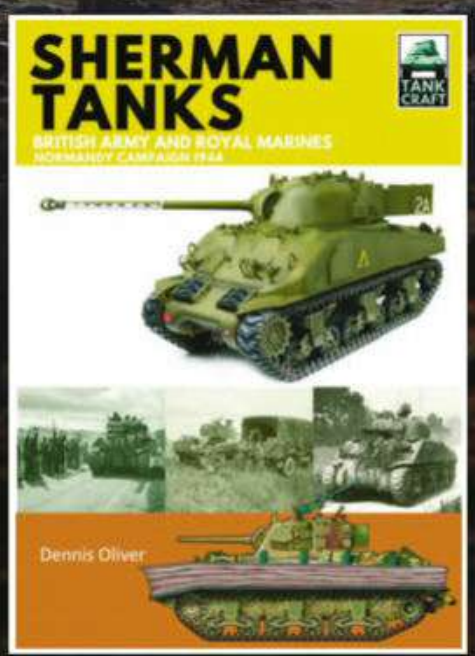

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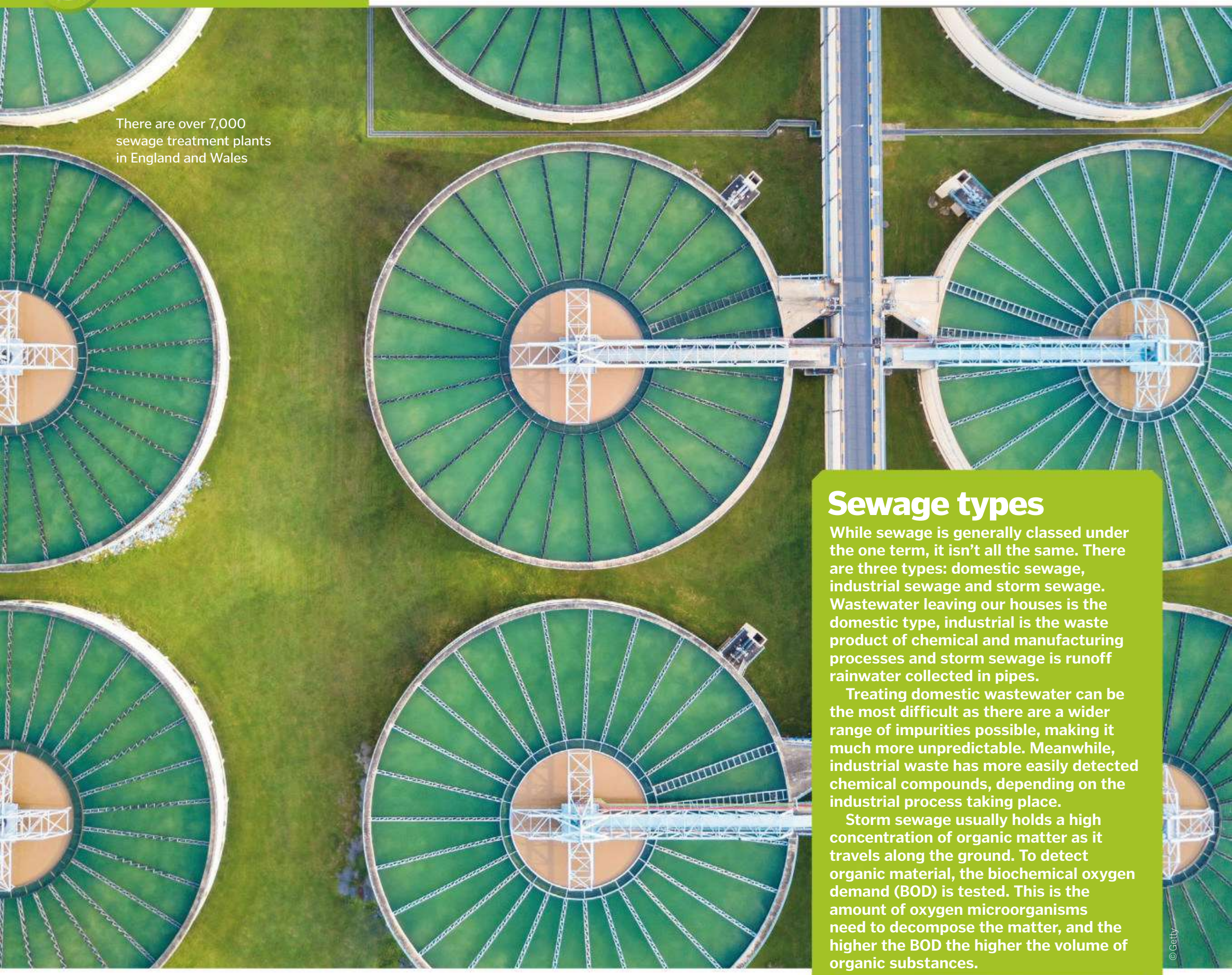

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Where does our sewage go?

From the moment you flush the toilet or pull the plug in the sink, follow the journey of wastewater

In countries where water is readily available to us, we can sometimes take it for granted. It has so many uses, either personally in our own homes, as part of most industrial processes or in agriculture to help us grow our food. However, once we have utilised this water, it becomes contaminated and can be a danger to our health. What do we do with the water then?

Most wastewater follows the same route as it is directed underground and into treatment plants. Having learned from previous issues throughout history, we know that dumping sewage back into rivers and oceans untreated has dire consequences for everyone's health. Sewage systems are tasked with the job of removing debris, from large plastic objects that have found their way into drains to smaller mineral particles such as grit or stones. Once contaminant-free, the water is returned to nature to repeat the cycle.

Sewage types

While sewage is generally classed under the one term, it isn't all the same. There are three types: domestic sewage, industrial sewage and storm sewage. Wastewater leaving our houses is the domestic type, industrial is the waste product of chemical and manufacturing processes and storm sewage is runoff rainwater collected in pipes.

Treating domestic wastewater can be the most difficult as there are a wider range of impurities possible, making it much more unpredictable. Meanwhile, industrial waste has more easily detected chemical compounds, depending on the industrial process taking place.

Storm sewage usually holds a high concentration of organic matter as it travels along the ground. To detect organic material, the biochemical oxygen demand (BOD) is tested. This is the amount of oxygen microorganisms need to decompose the matter, and the higher the BOD the higher the volume of organic substances.

© Alamy

Some wastewater systems can't handle the large volumes of storm sewage, so this water often bypasses in large pipes

The first toilets were connected to cesspools, not sewers to carry sewage away

© Alamy

Early methods

Today's approach to managing and reusing wastewater seems an efficient one, especially when compared to past methods. In fact, during the Middle Ages there didn't really seem to be many methods in place at all. Cesspools were often used for sewage – or households would simply pour their wastewater into gutters and let the rain dictate its path down the drain.

This demonstrates the importance of today's systems, as disposing of wastewater this way resulted in diseases such as cholera and became a serious threat to public health and hygiene. Following this, it was decided that waste should be transported away from living areas and released straight into lakes. Without any purification process, this led to a growing water-pollution problem.

Aerial view of Maple Lodge Water Treatment Works, Hertfordshire

© Getty

Sorting out the sewage

Follow wastewater's flow as it is refreshed for reuse

Industrial waste

The activities taking place within factories, shops and other industrial buildings produce large volumes of water. Some factories produce toxic waste, which is not accepted in the public sewerage system.

Flushing water

Every day an average person in the UK produces 150 litres of waste water. Through activities such as cooking, washing and flushing the toilet, the litres add up – and it all needs somewhere to go.

Environment preparation

Before the water can be released back into rivers and lakes, finishing touches need to be put in place to make it suitable for the surrounding wildlife and environment. Sometimes beneficial nutrients can be added. Other times nutrient-removal technology is required, such as phosphorus reduction. Too much of this entering lakes can result in increased algal growth, depleting its oxygen supply and killing other life.

Screening

One of the first treatment processes is screening. This removes any major pieces of debris that are too large for the rest of the system. Plastics and cloths are among those separated.

Grit filtering

When water reaches this tank, its flow slows down. This lets any grit particles sink to the bottom. Grit doesn't have to be silica sand, as commonly thought, but can include concrete, coffee, eggshells and other food waste.

Agricultural use

Abundant in nitrogen and phosphorus, condensed 'sludge cakes' are happily received by farmers, who use them to help their soil thrive and restore any damaged land. This efficient process means that the 'waste' isn't really wasted at all.

Settlement tank

As an essential section after the biological processes, this tank removes the bacteria that was added for use in the previous treatment tank. To do this, water is filtered through ceramic material.

Treating leftovers

Though it was unwanted in the water, leftover sludge has some desirable properties for soil. However, for it to be reused it needs to be treated to remove pathogens. After bacteria breaks these down, the sludge enters a centrifuge that tightly packs the waste for transportation.

Biological stage

Any matter that has made it to this stage in the process is either dissolved in the water or is incredibly light and floats. Microorganisms such as bacteria are used in this stage to actively break this down.

Sourcing energy

Waste products extracted have no use in the water, but can be used as a renewable method of generating electricity. Microorganisms break down the waste materials to produce methane. This gas, along with gas released at other stages, is then used for both heat and electricity production.

Removing grit

When the grit accumulates at the bottom of the tank, it is scraped away out of the system and taken to landfill.

Primary treatment

Into these sizeable tanks, sewage water constantly flows. Entering a large space causes the water to slow to a still. This allows fats to float to the top of the basin and any remaining heavier items to sink.

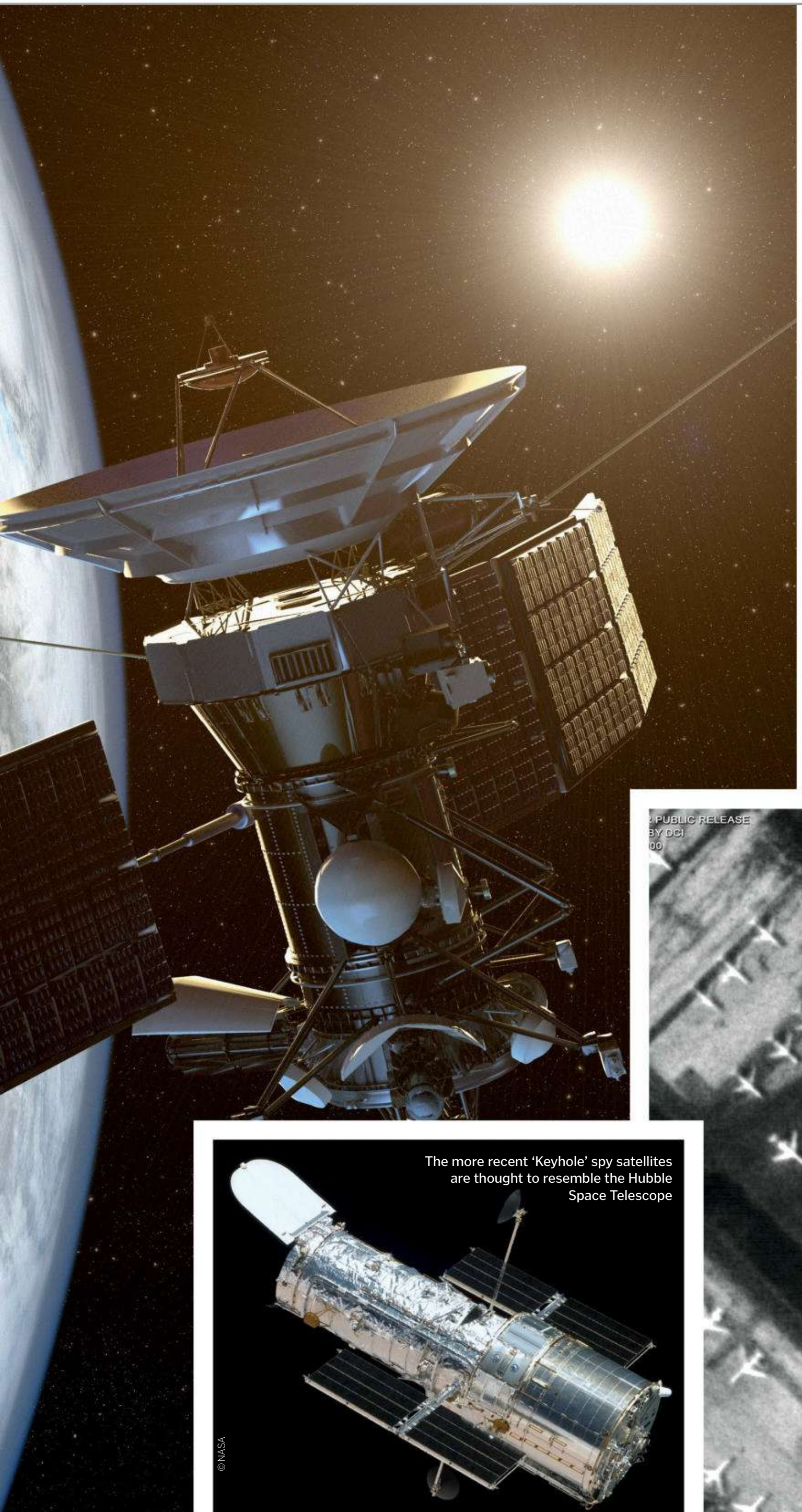
© Illustration by Adrian Mann

EYES IN THE SKY

How all-seeing satellites watch the world from the safety of space

Words by **Baljeet Panesar**

© Getty



Ever since the launch of the first satellite, Sputnik, by the USSR in October 1957, thousands more have orbited – and remain orbiting – the Earth. We don't tend to hear about reconnaissance, or spy satellites though, and as their missions are classified, their equipment and capabilities are often not disclosed. Hundreds of these secretive spies in the sky have been launched since the 1960s.

Spy satellites are used for both military and intelligence purposes, including detecting troop movements, monitoring the dismantling of nuclear weapons and radio signals, spotting missile launches and providing precise positional information. Flying high above the surface of Earth, these eyes are free to scan the ground below with their most important asset – their onboard camera. It's estimated that these satellites can see objects on the ground that are just ten centimetres across – enough to see an individual person in a crowd. These use the same technology that's in your smartphone – a charge-coupled device (CCD) – a sensor that converts light into electrical signals. These are stored on the satellite's onboard computer until it can send the encrypted information back to the ground. Satellites must also have a source of power, in many cases either solar or nuclear, and a means of controlling their altitude, such as via thrusters. There are also radio-listening spy satellites that can listen to radio signals that are being transmitted by another satellite.

A KH-9 satellite image of an airfield near Moscow, taken in 1979

© NRO

The more recent 'Keyhole' spy satellites are thought to resemble the Hubble Space Telescope

© NASA

AR ZONE!

Anatomy of a spy satellite

Discover what lies within these top-secret electronic spies

Relay antenna
Satellites use radio waves to downlink imagery back to ground stations on Earth from an altitude of about 320 kilometres.

Thrusters
From manoeuvring itself into the correct orbit to maintaining its position on a target, all satellites need a way of moving through space.

High-resolution camera
CCDs gather images to form a digital photograph that's transmitted back to Earth.

Primary mirror
Reportedly some spy satellites have a primary mirror that's 2.4-metres wide – the same diameter as that of the Hubble Space Telescope.

Solar panels
Large, fold-out panels harness the Sun's energy into electricity to power the satellite.

Avionics
The satellite's electrical systems and software act as its brain, telling it what to do and where it needs to be.

Fuel
A fuel called hydrazine is used to make slight adjustments to the orbit of the satellite and avoid collisions.

Secondary mirror
A steerable secondary mirror helps to enhance the sharpness of the images taken by the satellite.

5 FACTS ABOUT MILITARY AND INTELLIGENCE SATELLITES

1 Zenit
The USSR's Zenit satellites were launched between 1961 and 1994, disguised as scientific exploration missions using the name Kosmos. Over 500 satellites were launched between 1981 and 1994.

2 SAR-Lupe
Germany's first reconnaissance mission is used by the military, and it's made up of five satellites that were launched over a period of two years.

3 Information Gathering Satellite (IGS)
After a North Korean missile test over Japan in 1998, Japan's first spy satellite was launched in March 2003. The country's most recent intelligence-gathering satellite was launched in February 2020.

4 Zircon
This was supposed to be Britain's first spy satellite, but the project was cancelled in 1987 because it was too expensive.

5 KH-11 Kennen
The first US spy satellite that used digital imaging was launched in 1976, and over its lifetime there have been five different generations.

AR ZONE! SCAN HERE

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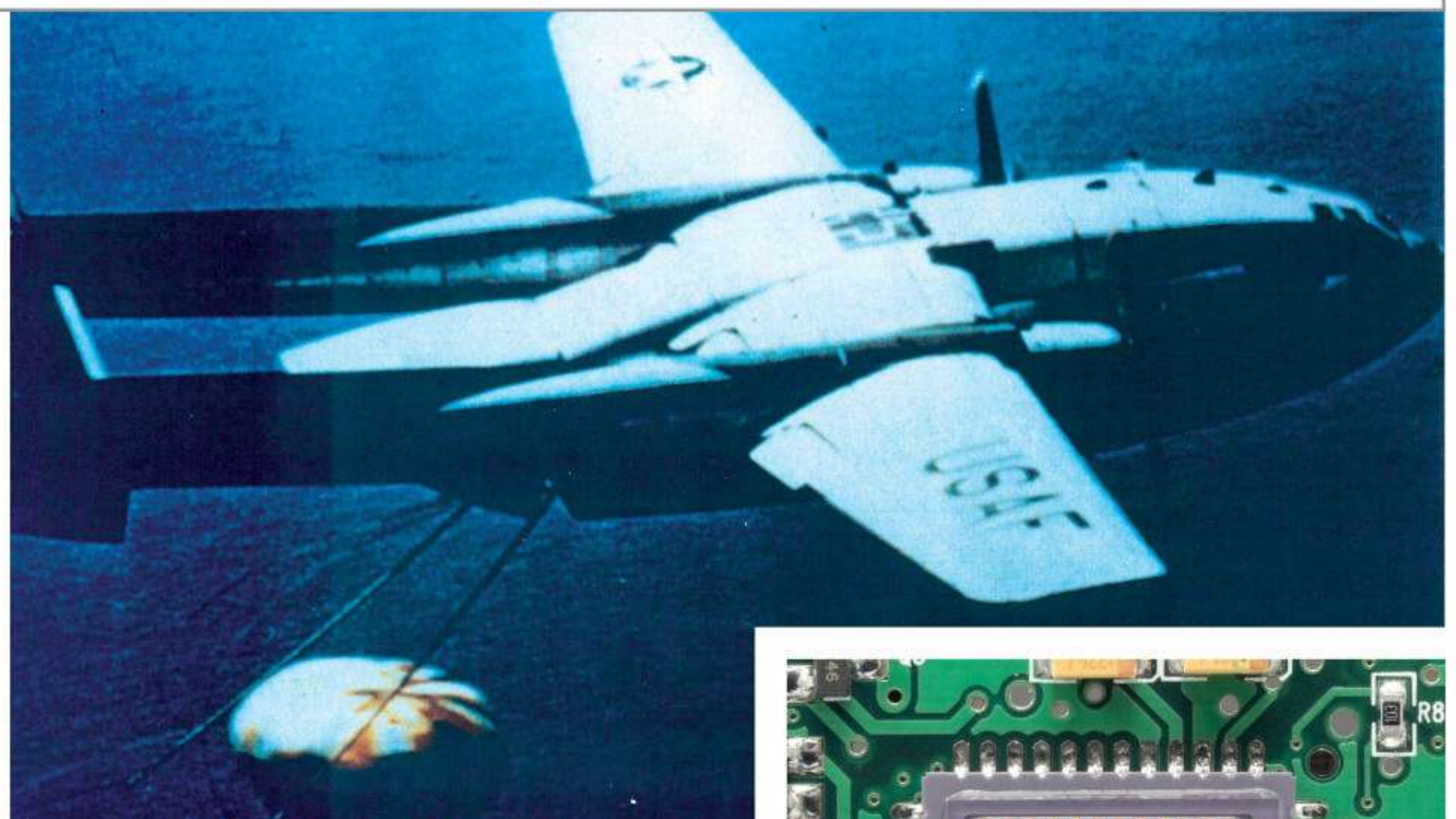

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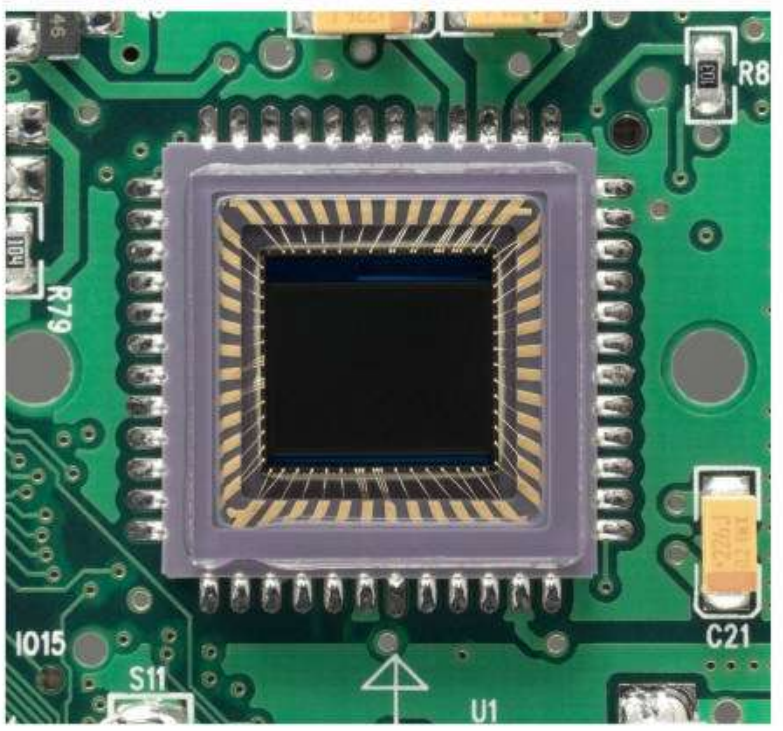
A C-119 aircraft catches a recovery capsule that contained the first reconnaissance images from space in mid-air



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Silicon is used to make CCDs because of its semiconductor properties

During the height of the Cold War, the US felt threatened by a nuclear attack from the Soviet Union. The US used aircraft and balloons to spy on the Soviets, but after one of the US' U-2 spy planes was shot down, the country needed other ways to gather intelligence, so space-based photo reconnaissance satellites were developed. The programme was called Corona and was approved months after the Soviets launched Sputnik.

These early spy satellites, however, were nothing like modern-day reconnaissance satellites; they used photographic film to store photos that were then returned to Earth in a 'film bucket' that was caught by an aeroplane in mid-air at about 4,572 metres. Modern-day satellites can stay in orbit for years, while the Corona satellites were limited by the amount of photographic film they had on board – at most they could only stay in orbit for a few weeks. Over its 12-year lifetime the Corona programme collected more than 800,000 images, each of which had to be carefully scrutinised by humans working on the project.

Recently the National Reconnaissance Office (NRO) has been working on an elusive project named Sentient, an AI spy system that's like an all-knowing, all-seeing brain in the sky. The programme can process vast amounts of information and combines this with satellite data to learn about the world below and respond in real time. Given its classified nature, however, its true capabilities will never be known, and it could be used without us ever knowing.

Satellite-on-satellite spying?

On 20 January 2020, something highly concerning happened hundreds of miles above the Earth's surface. A Russian inspector satellite, called Kosmos 2542, manoeuvred itself behind USA-245, an imaging spy satellite. Instead of passing each other every 11 to 12 days, however, there's now less than 300 kilometres between them. Experts believe that the Russian satellite is trying to gather information about the US mission; its radio-frequency probe could tell the Russians what pictures it's taking and how it processes the data. What's even more suspicious is that they're closest to each other when in sunlight – the perfect conditions for surveillance.

Although the evidence is coincidental, Russia's not breaking any rules, so there isn't much that the US can do about it. There are, however, growing concerns about the increasing militarisation of space.

A Delta IV Heavy rocket was used to launch USA-245 on 28 August 2013

© U.S. Air Force/Joe Davila

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How metal detectors work

From beachfront hobbies to saving lives, these devices have many applications

Words by **Ailsa Harvey**

Metal detectors come in a range of shapes and sizes, and though they all share the same purpose of finding buried metal objects, they can be used in many different ways. You may see people patrolling with a metal detector in hand and wonder how much fun it could possibly be, but the main reward of this hobby comes at rare and unexpected moments.

From the moment the metal detector is turned on, the detectorist walks in anticipation of the buzzing signal that tells them a metal object is close by. Following this, the peak of their excitement – and often the cause of subsequent disappointment – is the big reveal. Have they stumbled across precious treasure? Or will they just end up picking up someone else's litter? Either way, for many people metal detecting is all about the search.

More expensive and sophisticated detectors can be used in safety and security. Technology found in handheld metal detectors can also be utilised to monitor items people take abroad or into protected buildings. The electronic doorways you walk through in airport security can reveal any prohibited items on your person, while another detector scans your bags. While these are much more high-tech, all metal detectors use the core principles of electromagnetism that were seen in Alexander Graham Bell's first metal detector in 1881.

Types of detector

All metal detectors use electricity-to-magnetism conversions, but there are three different types that use different electromagnetic frequencies. Most amateur metal detector users will use the simplest type. These have a fixed low frequency of less than 30 kHz and are most commonly used for treasure hunts.

Higher frequency detectors, called pulse induction (PI) detectors, use signals in short pulses. These are better for finding items deeper in the ground. The third metal detector type is full-band spectrum, or FBS. These use different frequencies at the same time, so are able to pick up a larger range of items from different distances. Some advanced detectors can differentiate between the types of metal discovered and how far away finds are.

© Alamy

Waterproof metal detectors are used to explore the depths of the ocean

Tips for treasure hunters

Prepare for rubbish

For every piece of treasure you find you are likely to find many more tin cans, bottle tops or foil pieces. Persistence is key.

Find the best spots

If you're looking for items of historic value, check with historians – but don't forget to ask for permission from the landowner!

Go after rainfall

When the ground is wet it becomes a better conductor of electricity. Not only will it be easier to detect metal, but also easier to recover items from deep soil.

Stay flat

When scanning the floor, make sure the coils are parallel to the ground. If part of the detector is lifted too high you could miss out on potential treasure.

Sweep surfaces

Sometimes tiny pieces of rubbish or minerals can set off the detector. Removing any that could be lingering above ground prevents unnecessary digging.

Follow success

If you uncover something impressive, don't stop looking. Often items are found together, so make sure you check the surrounding area.

© F. Honoré

This is one of the first metal detectors. It was used in World War I to locate bombs

How is metal detected?

Searching below ground, these devices interact with buried metal to help you find treasure

Stabiliser
Found on some metal detectors, this simple-yet-effective addition allows comfort and control during treasure hunting. Supporting your arm, it allows the detector to be held steadily.

Receiver coil
This coil is responsible for alerting the person using the detector to metal below. Connected to a loudspeaker, when the coil comes into contact with the metal's magnetic field, electricity is generated to create a buzzing or clicking noise.

Battery power
The top of the metal detector houses a battery. This battery is responsible for activating the outside coil by passing electricity down the handle.

Transmitter coil
When electricity travels through this coil, a magnetic field is created around it.

Control box
This is where the speaker, battery and controls are stored.

Handle
This is long enough that the user doesn't need to crouch.

Cable
Twisted around the handle, it transfers power to the coil.

Affecting atoms
As the detector's magnetic field moves over the metal in the ground, the movement of electrons around the metal's atoms is altered.

Making magnetism
The magnetic field from the detector creates a new magnetic field around the metal. This is what will be detected.

Getting closer
Once alerted to metal in the area, the exact spot needs to be located. As the detector is moved closer to the metal, the magnetic field becomes stronger and creates a louder noise.

© Illustration by The Art Agency/Nick Sellers

TOP 5 DISCOVERIES

1 THE HAND OF FAITH
Kingower, Australia, 1980
Lying just 30 centimetres below ground level, Kevin Hillier's metal-detecting hobby proved fruitful when he stumbled across a mesmerising 27-kilogram golden nugget near Kingower in Australia. Dubbed the Hand of Faith, it was the largest piece of gold ever found using a metal detector and bagged Hillier over $1 million dollars.

2 BRONZE AGE AXES
Dorset, UK, 2008
After dropping some children off for a school trip, bus driver Tom Peirce pulled out his metal detector. He dug only 25 centimetres into the ground to find the head of a bronze-age axe. Further digging led to the discovery of nearly 500 bronze artefacts that date back roughly 3,000 years. They were thought to have been buried as an offering to the gods, and it's one of the largest finds of its kind in the UK.

3 RING FINGER
Montana, US, 1995
At the site of the infamous 1876 Battle of Little Bighorn, a volunteer archaeologist came across a finger bone still wearing a wedding ring. They discovered this was the body of a soldier who was killed alongside the troops of Lieutenant colonel George Custer.

4 SPACE ROCK
Albuquerque, US, 2011
13-year-old Jansen Lyons from New Mexico was using a cheap homemade metal detector in the Albuquerque suburb of Rio Rancho when he discovered a 0.9-kilogram meteorite. The nickel-iron meteorite is thought to have hit Earth 10,000 years ago.

5 CHARIOT BURIAL
Pembrokeshire, Wales, 2018
Some finds are of much higher historical importance than monetary value. In the middle of an empty Welsh field, Mike Smith unearthed a small Celtic harness decoration, dated to be from 25 to 75 CE. Later he discovered that it was part of the first Iron Age chariot burial found in Wales. He then returned to retrieve an entire horse skeleton and carriage. This highlighted the first known Iron Age settlement in the area.

Perfect pizza explained

What's the ideal way to make this tasty Italian dish?

Words by **Ailsa Harvey**

From its humble beginning, sold only by street vendors in the Italian city of Naples, pizza has become much more than a delicious source of cheap food. Each year, 5 billion pizzas are sold around the world. You can find them in the frozen section of almost every supermarket, have them made fresh from the menu at a restaurant or you can travel to their roots and try an original pizza experience from a top chef in Italy.

Pizzas first came into existence as the ideal food source for poverty-stricken people in 18th-century Naples. It was cheap, easy to make and tasty to eat. These characteristics are still important, but the beauty of today's pizzas is that they can be what you want them to be. Whether it's topped with the smoky taste of bacon, the polarising sweetness of pineapple or the simple cheese-and-tomato Margherita, pizza can have it all.

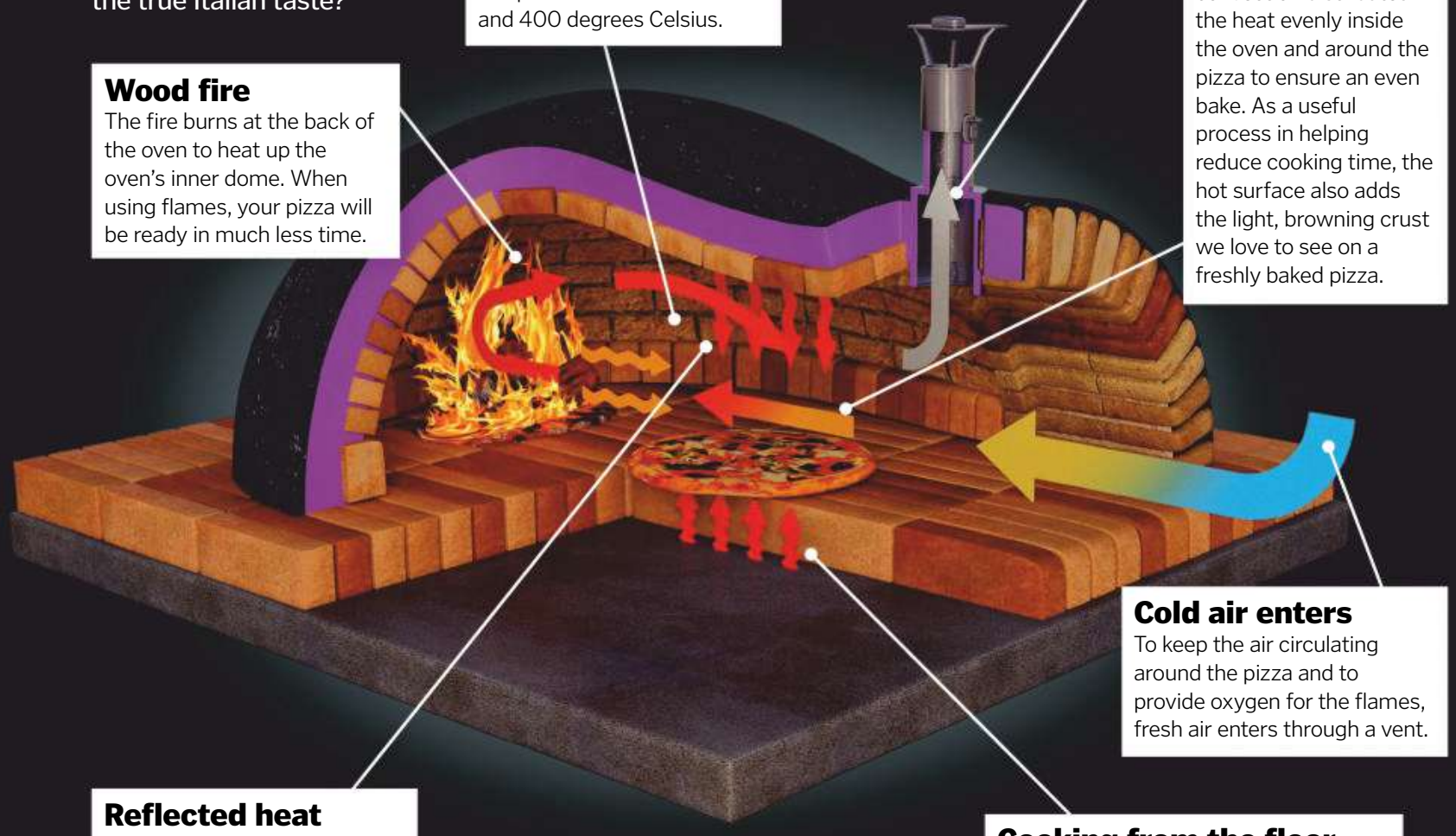
We can all imagine our own personal piece of perfect pizza, but what steps can we take to bake our pizzas to be the best they can be, according to science? Outside of Italy, fast-food chains have removed some of the authenticity from the process. It's both a winning blend of ingredients and method that allows chefs to create a perfect pizza.

© Getty

Wood-fired ovens can help pizza toppings retain nutrients and make them taste delicious

Inside the pizza oven

How do these ovens provide the true Italian taste?



Heat distribution
Larger ovens will require more time to become fully heated. Once hot enough it is designed to retain an even temperature at between 300 and 400 degrees Celsius.

Smoke exit
Smoke needs to exit the oven before it builds up. Too much of it can cause the pizza to adopt an overpowering flavour.

Convection cooking
As air temperature increases, it rises around the pizza. This convection distributes the heat evenly inside the oven and around the pizza to ensure an even bake. As a useful process in helping reduce cooking time, the hot surface also adds the light, browning crust we love to see on a freshly baked pizza.

Wood fire
The fire burns at the back of the oven to heat up the oven's inner dome. When using flames, your pizza will be ready in much less time.

Cold air enters
To keep the air circulating around the pizza and to provide oxygen for the flames, fresh air enters through a vent.

Reflected heat
Heat from the flames can be transferred to the food by being reflected off the walls of the dome and onto the pizza.

Cooking from the floor
Designed to give the pizza the best all-round finish, wood-fired pizza ovens store heat in the oven floor. This radiates back up to the bottom of the pizza and helps to establish an even heat.

AR ZONE! SCAN HERE

The physics of pizza-making

Liquid limits
Adding water to the dough base alters the properties of gluten. It acts to hydrate the gluten proteins, changing the consistency. If not enough water is added then the proteins gliadin and glutenin won't combine well and the dough will easily tear. If you add too much water the protein fibres will be too loose and the base will lose its shape.

Need to knead
To keep the gluten bonds flexible, knead the dough. This will unfold the gluten chains into a stretchy dough for trapping air. Adding a pinch of salt in kneading can neutralise electrically charged particles and help them move across each other more readily.

Handling the heat
For the most authentic pizza, bake the dough in a wood-fired pizza oven at 330 degrees Celsius. If baking at home with an electric oven, preheat to 230 degrees Celsius.

Timing to perfection
At these temperatures, keep the pizza in the wood-fired oven for two minutes, and the electric oven for just 170 seconds.

Getting a grilling
Once the base is cooked, turning the temperature to its maximum and switching to the grill setting for a matter of a few seconds will achieve base crispness and gooey cheese, without causing the pizza to dry out.

Choosing your cheese
Mozzarella is considered the most desirable cheese for pizza topping. As cheese heats up, the water inside boils, with steam creating a bubbling effect. This cheese is more elastic than other varieties such as cheddar and edam and creates a stretchy well-bubbling surface. It also has the ideal oil content to create the browning top associated with a well-baked pizza.

© Illustration by Nicholas Forder

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NUCLEAR ARMS RACE

How two feuding nations stockpiled nuclear weapons in a race to become the dominant military power on Earth

Words by **Scott Dutfield**

Ever since the atom was split in 1917 by physicist Ernest Rutherford, scientists and military engineers alike have worked to weaponise science, culminating in some of the most devastating attacks in human history.

In 1945, two American atomic bombs, dubbed 'Little Boy' and 'Fat Man', were devastatingly dropped on two Japanese cities, Hiroshima and Nagasaki, marking the end of World War II. Seen as a prominent nuclear force at the time, the US had displayed to the world its military power, and in turn stoked a political fire between itself and the USSR, the country now known as Russia. By 1949 the USSR had developed and detonated its first nuclear bomb, RDS-1, also known as 'First Lightning', and almost like the sound of a starting gun, it signalled the start of a nuclear arms race with the US. Who would be the first to cross the finish line, and what would that finish line mean? Total annihilation, perhaps?

Both nations continued developing and stockpiling nuclear weapons in the following years. However, in 1952 the US pulled ahead with the creation of the hydrogen bomb. Previous atomic bombs, such as those used on Hiroshima, utilised the explosive energy produced in nuclear fission. Uranium and plutonium were used in this process to create a chain reaction of splitting atoms. A hydrogen bomb uses nuclear fusion with the addition of tritium and a hydrogen isotope called deuterium. In this reaction atoms are forced together, releasing explosive energy around 1,000 times more powerful than the WWII bombs.

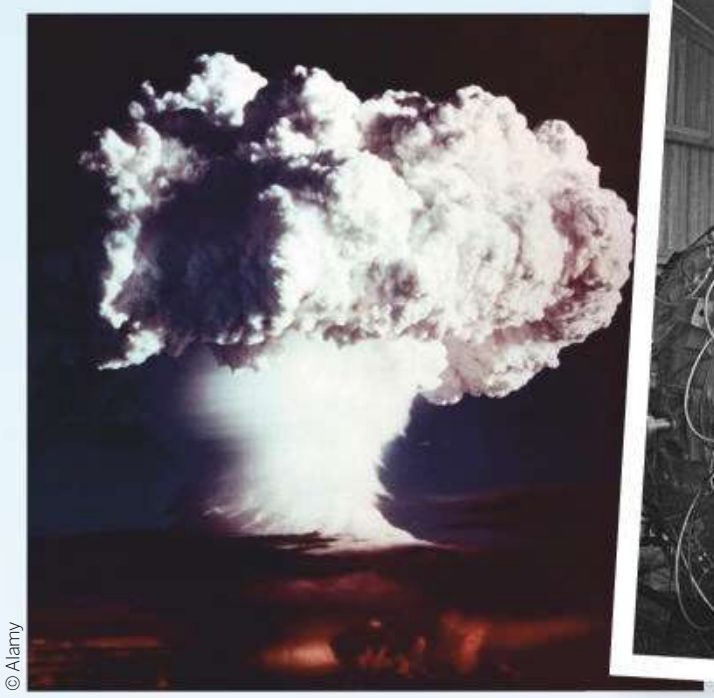
© Alamy

After the US had detonated its hydrogen bomb in Eniwetok Atoll, a chain of islands in the Pacific, it only took the USSR a year to test its own hydrogen creation, presenting the very real threat of globally destructive nuclear warfare. As political tension grew between the two nations during the Cold War, the conflict reached a boiling point in what is now known as the Cuban Missile Crisis of 1962.

In a 13-day standoff between the US and the USSR, the world held its breath after the US discovered that the USSR had been building and storing nuclear weapons in Cuba, just 145 kilometres from Florida. Creating a blockade around the island, the US prevented military supplies from entering the country in hopes of starving USSR nuclear supplies to Cuba. This act of quarantining Cuba was seen as an act of aggression by the USSR, and diplomatic resolution appeared to be unachievable.

However, much to everyone's surprise a resolution was found after America threatened to invade Cuba, and the USSR retreated from the island. It later came to light that the USSR's retreat came with a condition: that the US would remove its nuclear arsenal from Turkey. The two nations constructed a doctrine called mutual assured destruction, in which both nations recognised that if one launched missiles against the other, the retaliation would lead to both countries suffering terrible nuclear fallout.

By July 1968 the Treaty on the Non-Proliferation of Nuclear Weapons was signed by the US, the Soviets and the British. The treaty sought to prevent any country without nuclear weapons at the time from developing them. In the years that followed, several nuclear treaties between the US and the Soviet Union were signed, such as the Strategic Arms Limitation Talks (SALT I) and SALT II, to ease tensions between them and limit production of nuclear weapons.



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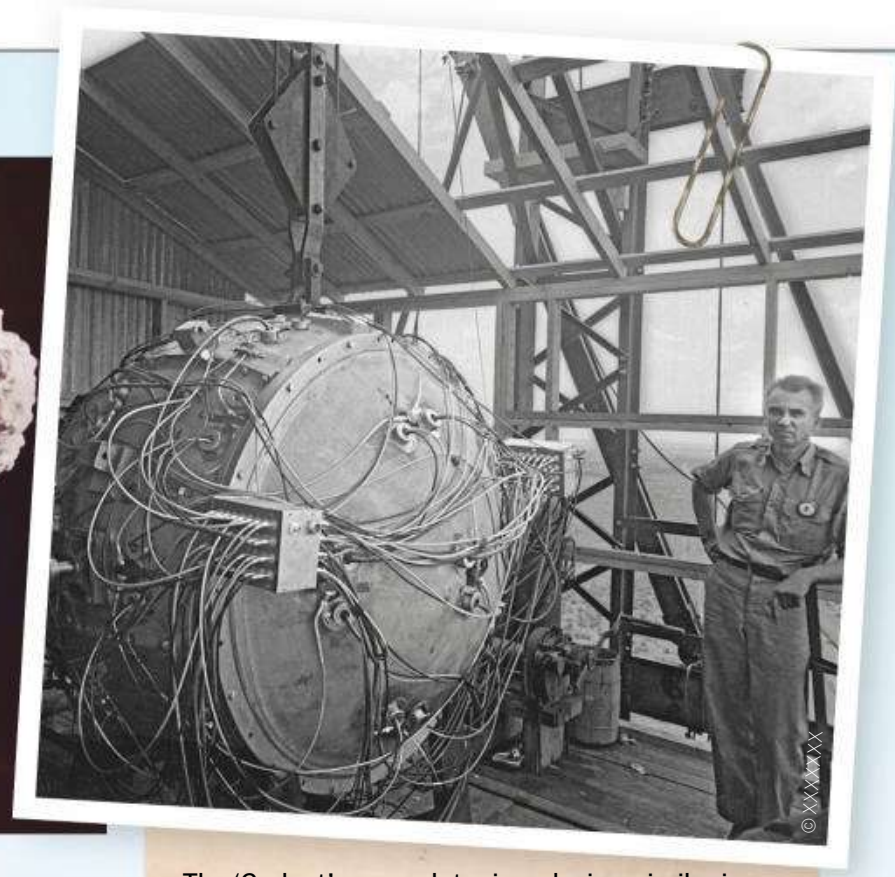
The Americans' first full-scale hydrogen bomb was detonated in 1952



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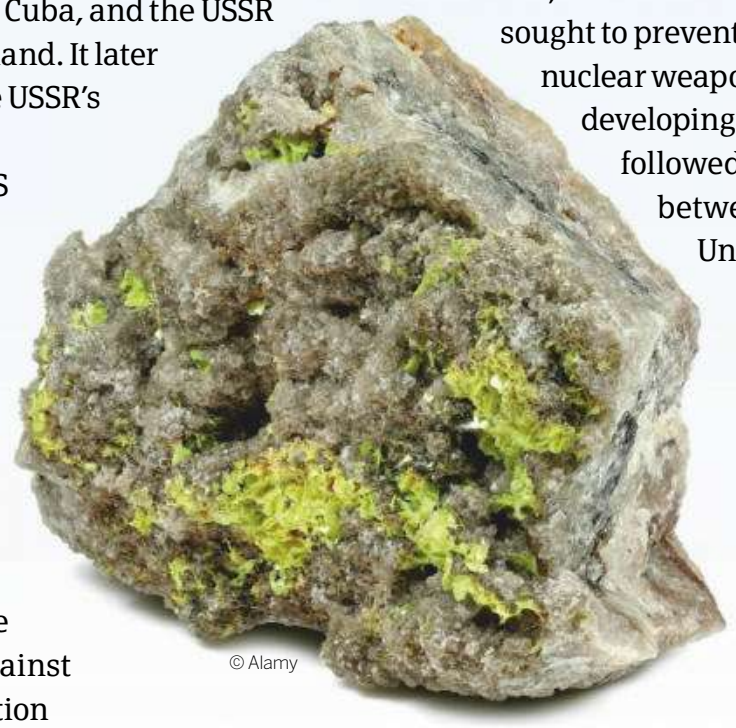
The 'Gadget' was a plutonium device, similar in design to the Fat Man bomb that was later dropped on Nagasaki, Japan



© Alamy

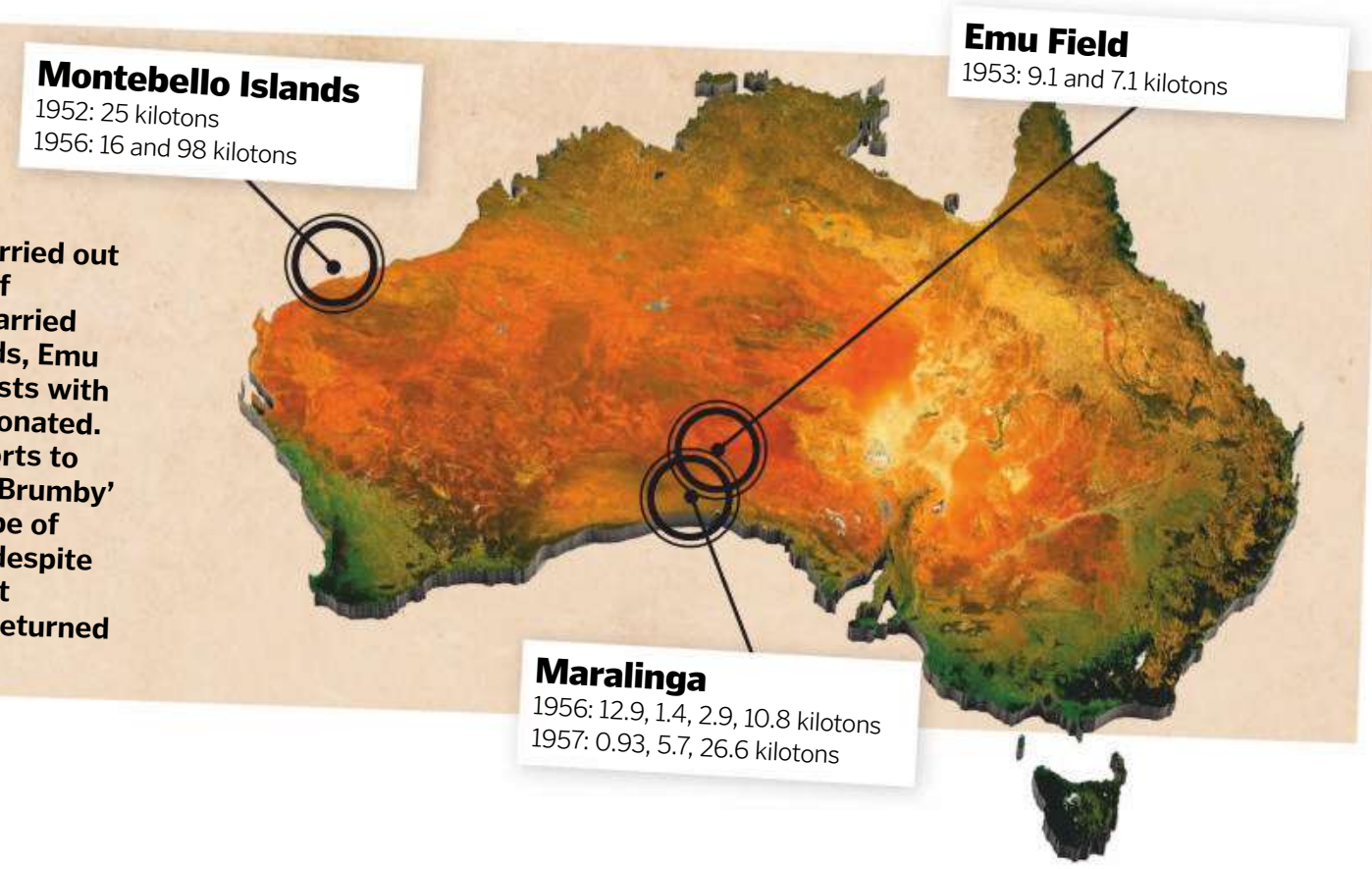
Autunite can be used as an ore of uranium

BUILDING THE A-BOMB

The Manhattan Project changed the course of history forever, ultimately leading to the death of hundreds of thousands of people. After the discovery of nuclear fission by German scientists Otto Hahn and Fritz Strassmann in 1938, fears grew in the US that Nazi Germany may be able to develop the first atomic bomb. To beat the Germans to the punch, President Franklin Delano Roosevelt assembled a team of scientists and military experts, known as the Uranium Committee, to evaluate the use of nuclear fission and become the first nation to weaponise the newfound science. Having deduced its potential for the creation of a new type of bomb, the Manhattan Project was formed in 1942, named after the location of the office headquarters. Three years later the project bore its first explosive fruit, the 'Gadget' plutonium bomb, an invention that led to the nuclear arms race.

THE UK BOMBS AUSTRALIA

Between 1952 and 1963 the United Kingdom carried out a series of nuclear tests on the arid continent of Australia, with the government's permission. Carried out over three locations – the Montebello Islands, Emu Field and Maralinga – 12 major nuclear bomb tests with a yield ranging from 1.4 to 98 kilotons were detonated. In the years that followed, the British made efforts to clean up their nuclear mess. In 1967 'Operation Brumby' removed and buried waste and debris in the hope of diluting the UK's radioactive residue. However, despite its best efforts, 60 years on the land has still not completely recovered, and wildlife has still not returned to these contaminated areas.



DID YOU KNOW? *Uranium is around 500 times more abundant than gold on Earth*

TRAJECTORY TO A NUCLEAR WORLD

1945 United States
The world's first successful detonation of a nuclear bomb occurred in July 1945 at the Trinity test site, Jornada del Muerto desert, New Mexico.

1949 Soviet Union
In August 1949, the Soviet Union tested its first nuclear bomb, RDS-1, at the Semipalatinsk Test Site in what is now modern-day Kazakhstan.

1952 United Kingdom
Tested on islands off mainland Australia, the UK dropped its first bomb back in October 1952 after creating a nuclear programme in 1947.

1960 France
Entering the nuclear race in February 1960, France detonated its first bomb in the Sahara Desert of Algeria, called 'Gerboise Bleue', or Blue Jerboa, with an explosive yield of 70 kilotons.

1964 China
Following assistance from the Soivet Union until the late 1950s, in October 1964 China detonated its first nuclear bomb, code-named Project 596, releasing 22 kilotons of explosive power.

Mid-1950s to 1960s Israel
Although a nuclear test has never been conducted by Israel, it's widely believed that the country has nuclear capabilities.

1974 India
Beginning its nuclear programme in 1944, it wasn't until May 1974 that India showcased its military efforts with a eight-kiloton bomb, code-named 'Smiling Buddha'.

1998 Pakistan
As a retaliation to a series of nuclear tests conducted by India in 1998, Pakistan conducted its first nuclear tests, six to be exact, in May of the same year.

2006-2017 North Korea
Despite threats from the US against testing nuclear weapons, North Korea conducted six underground nuclear tests beneath the mountainous site called Punggye-ri since October 2006.

www.howitworksdaily.com

The scale of nuclear test explosions is enormous

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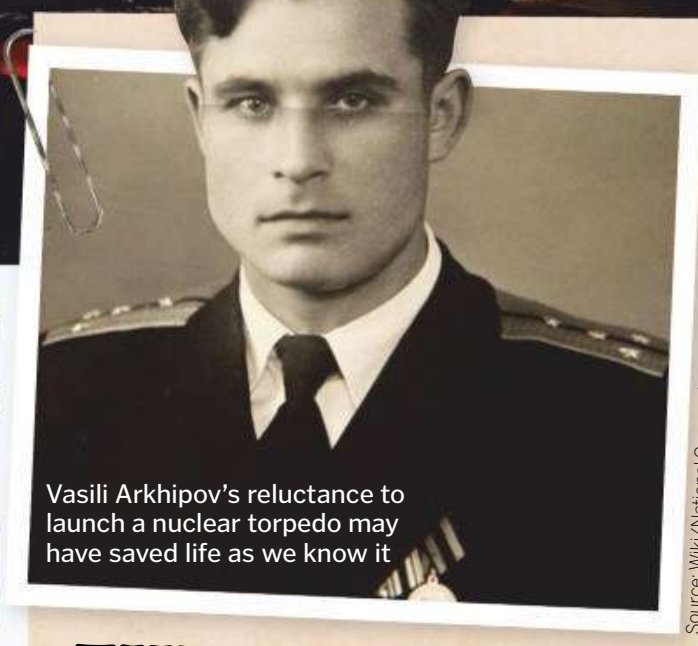


Vasili Arkhipov's reluctance to launch a nuclear torpedo may have saved life as we know it

Source: Wiki/National Geographic

"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION

VOL. CXII . No. 38,264 NEW YORK, MONDAY, OCTOBER 29, 1962 FIVE CENTS

U.S. AND SOVIET REACH ACCORD ON CUBA; KENNEDY ACCEPTS KHRUSHCHEV PLEDGE TO REMOVE MISSILES UNDER U.N. WATCH

DE GAULLE WINS 5 OF BALLOTS; ABSTENTIONS HIGH

DE GAULLE VOTES IN REFERENDUM. President de Gaulle casting ballot in Colombey-les-deux-Eglises.

THANT SETS VISIT

He Will Go to Havana Tomorrow to Seek Castro Consent

RUSSIAN ACCEDES

Tells President Work on Bases Is Halted —Invites Talks

CAPITAL HOPEFUL

Plans to End Blockade as Soon as Moscow Lives Up to Vow

Castro Asks Guantanamo; Strives to Repair Prestige

WARFARE ALTERS

Plane Veers Over Soviet, Kennedy Voices Regrets

PATROLS MAINTAIN

© Alamy

The Cuban Missile Crisis was the closest humankind has ever come to nuclear warfare

© US government

'Fat Man' was the second of only two nuclear weapons ever to be used in war

THE MAN WHO SAVED THE WORLD

During the Cuban Missile Crisis, a decision made by a single Soviet Navy officer potentially saved the entire world. After US President John F. Kennedy initiated a blockade on shipments to Cuba, a Soviet submarine was travelling towards the shores of the US, carrying a nuclear torpedo. As the submarine approached the blockade, several explosive charges were dropped into the surrounding waters by American ships in an attempt to ward away the submarine and force it to surface. However, with the threat of nuclear warfare looming, it's believed that captains aboard the vessel saw this as an indication that the war had already begun. Soviet protocol demanded that three high-ranking personnel must be in agreement to launch the nuclear weapon. Two of the submarine's officers had their detonation keys ready and waiting. However, the third, Vasili Alexandrovich Arkhipov, refused. It's reported that Arkhipov recognised the charges for what they were, and not as the instigation of World War III. Without all three officers in agreement, the launch was aborted and nuclear war was averted.

AR ZONE!

DEADLY DEFENCES

The UK's nuclear submarines patrol the country's coastline, armed and ready with nuclear warheads

The US tested nuclear weapons at Bikini Atoll during the 1940s and 1950s

© Alamy

Following direction
Aboard the Trident missile is a MK 6 stellar-inertial navigation system capable of delivering the warhead to within around 120 metres of its target.

Launch
Pressure from expanding gas within the storage tubes behind the submarine's fin builds until it's enough to launch the Trident missile.

Powerhouse
Held within the head of each missile are multiple independently targetable re-entry vehicles (MIRVs) – six 100 kiloton thermonuclear warheads.

UGM-133A Trident II D5
Length: **13 metres**
Weight: **58,500 kilograms**
Range: **12,000 kilometres**
Cost: **£41.3 million per missile**

AR ZONE! SCAN HERE

Flight
Once it escapes the water's surface and it's far enough away from the submarine that deployed it, the airborne missile uses a three-stage solid-propellant rocket to soar through the skies.

Floating storage
16 Trident missiles can be stored on each of the UK's four Vanguard-class submarines.

MODERN-DAY THREAT

Russia and the US have around ten times the number of warheads the rest of the world has combined

RUSSIA 6,490

THE US 5,800

FRANCE 300

CHINA 290

THE UK 215

PAKISTAN 150

INDIA 130

ISRAEL 80

NORTH KOREA 20

© Getty

In 1945, the first-ever nuclear device was detonated in the New Mexico desert

© Ploughshares Fund 2020

Illustration by Nicholas Forder

NUCLEAR WEAPONS by numbers

Fat Man and Little Boy killed over

200,000 PEOPLE

between the attacks on Hiroshima and Nagasaki, Japan

At today's consumption rate, there is around

230 YEARS

worth of uranium available from known sites on Earth

A nuclear explosion can reach temperatures of around

100 MILLION DEGREES CELSIUS

1,814 TONNES

The average uranium-mining waste created by manufacturing a single nuclear bomb

BETWEEN 1945 AND 2017 THERE HAVE BEEN

2,056

nuclear weapons tests around the world

50 MEGATONS

The most powerful known nuclear bomb wss the Russian RDS-202 Tsar Bomba, tested in 1961

80 KM RADIUS

An average nuclear weapon test would destroy everything within a

© Getty Images

Harry and Meghan struggled with heavy media interest during their roles as part of the royal family

Can you quit being king?

For those born into royalty, do their responsibilities ever end?

Words by **Ailsa Harvey**

To be a prince, princess, king or queen sounds like a fairy tale that many children dream of. But what is it really like to be born or married into a role of such importance? And if it isn't the life for you, is there a way out?

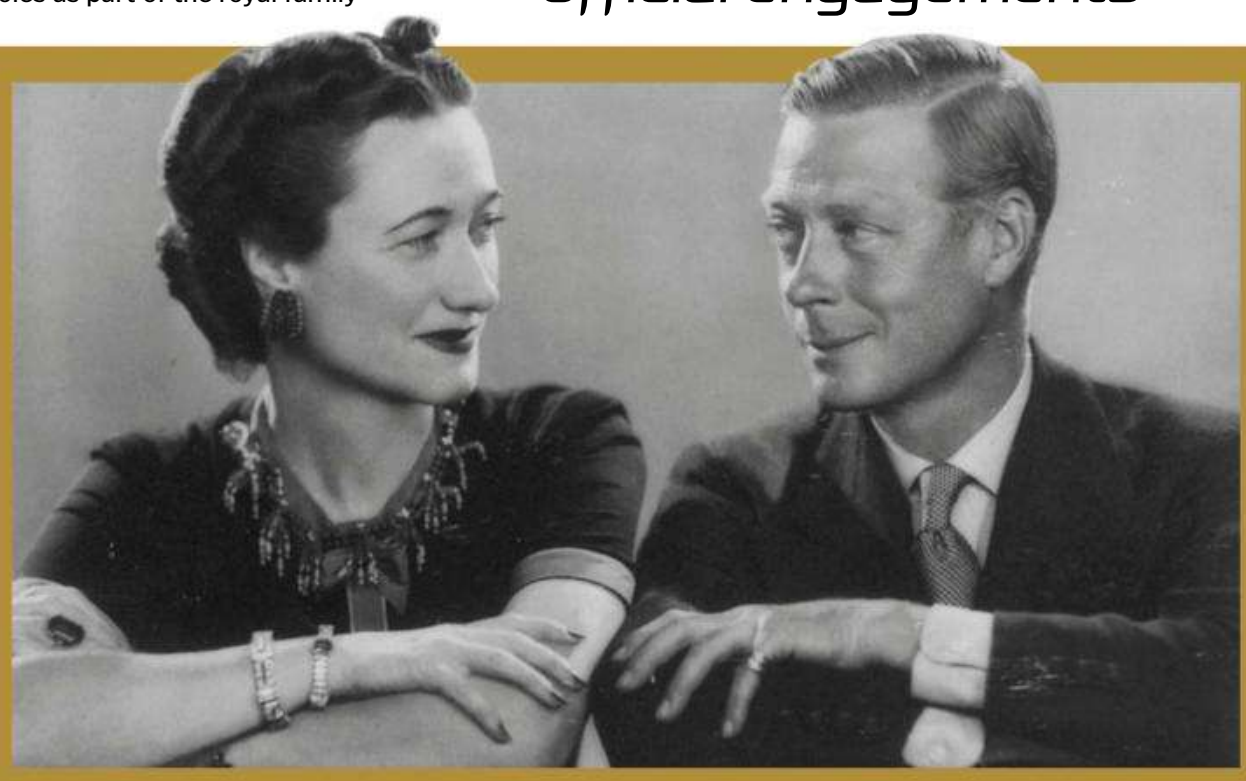
Recently the Duke and Duchess of Sussex, Prince Harry and Meghan Markle, decided to shift away from the public eye, dropping their titles and royal roles. Aiming to become completely financially independent, it symbolises a new era for British royals. Over the course of a year, Britain's royal family carries out over 2,000 official engagements. So with fewer family members carrying out these duties, there will be fewer engagements going forward. Each royal usually prioritises a cause to raise awareness for. Harry's was environmental work while Meghan often shone light on gender equality. Some worry that these causes will miss out. Others praise the couple for not just blindly following an ancient tradition.

"Over a year Britain's royal family carries out over 2,000 official engagements"

The last royal Brit to quit

As it stands, King Edward VIII is the only British king to have ditched his duties in modern times. After falling for an American, Wallis Simpson, Edward found himself more devoted to the divorcee than a role which forbade him from marrying her. This situation, which stemmed from the fact Wallis had previously been married, shows how views have adapted. The British royal family has become more flexible on subjects such as divorce, allowing Harry and Meghan to marry – Meghan also being an American divorcee. On 11 December 1936, Edward announced the news of his abdication on the radio, and the throne was passed on to his younger brother, George VI.

Edward is one of the shortest reigning British monarchs, abdicating so he could marry Wallis Simpson after just 326 days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Kings who quit

While many monarchs have been forced to abdicate, for some it was a choice

1935

Prajadhipok
King of Thailand
This king left for England after he had had enough of growing military rule in the country.

1936

Edward VIII
King of the United Kingdom
Retired from his position after royal rules stopped him marrying the woman of his choice.

1946

Victor Emmanuel III
King of Italy
Stood down to distance the monarchy from World War II.

1951

© Willem van de Poll

Leopold III
King of Belgium
Quit as king to stop retaliation against his illegal marriage.

1952

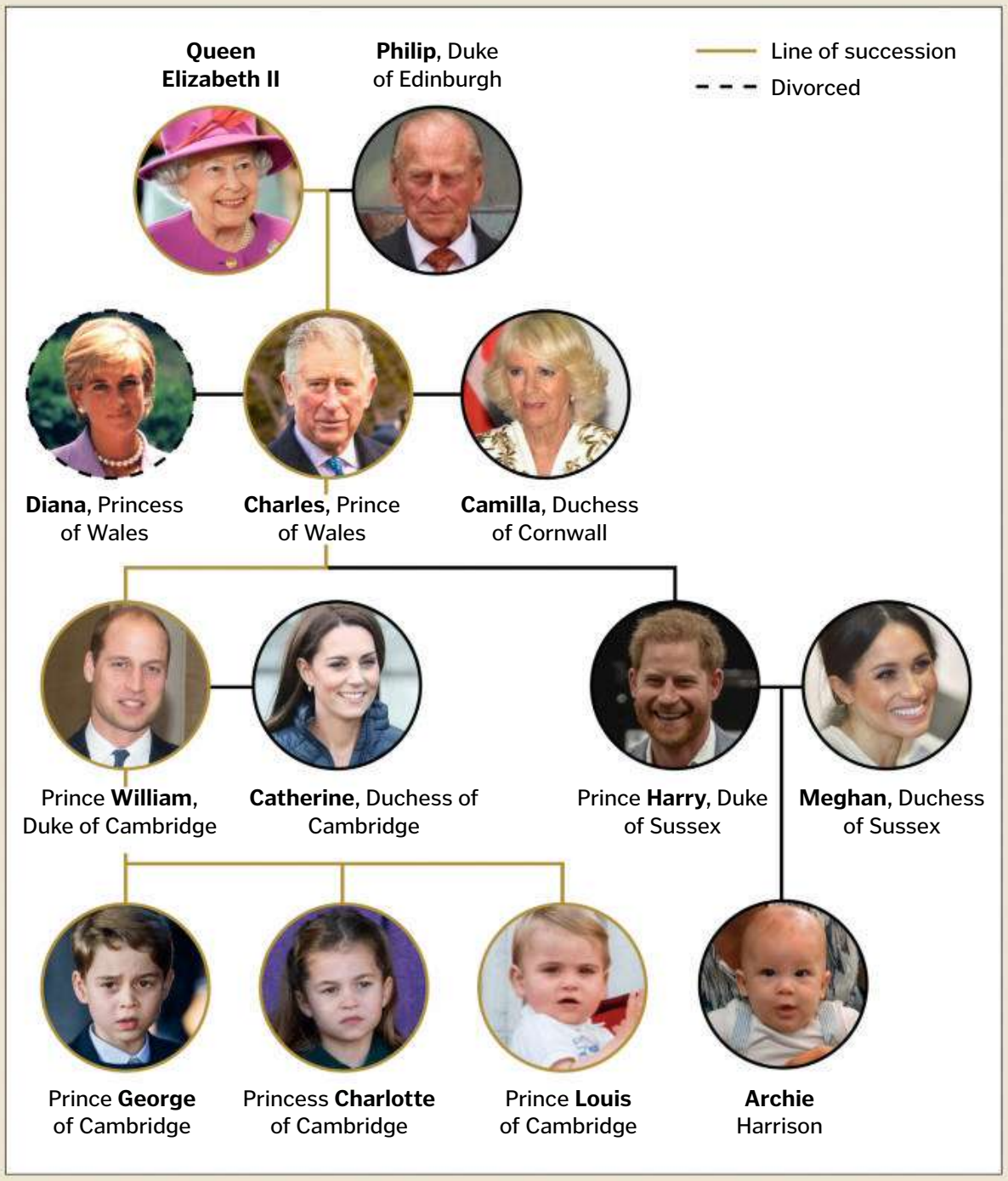
Talal
King of Jordan
Gave up his position as king to receive treatment for schizophrenia.

Losing Harry

Prince Harry and Meghan Markle recently chose to step back from their royal duties, but how will this impact the dynamic of the family? With Harry being a younger brother, Prince William is second in line for the throne after Prince Charles. Now that William and Kate have had three children, Harry has been pushed further back in the line, sitting sixth in line to the throne, so it is unlikely he would ever be king. Harry and Meghan's son, Archie, is classed as a royal baby despite having no title, as he was born into royalty – but any child they have from now on won't officially be part of the royal family in the same way. The royals claim to strengthen national unity, but many question how this will be possible with Harry and Meghan's decision to divide the family at its heart.

© Alamy

Harry sits outside the direct line of succession



© Getty Images

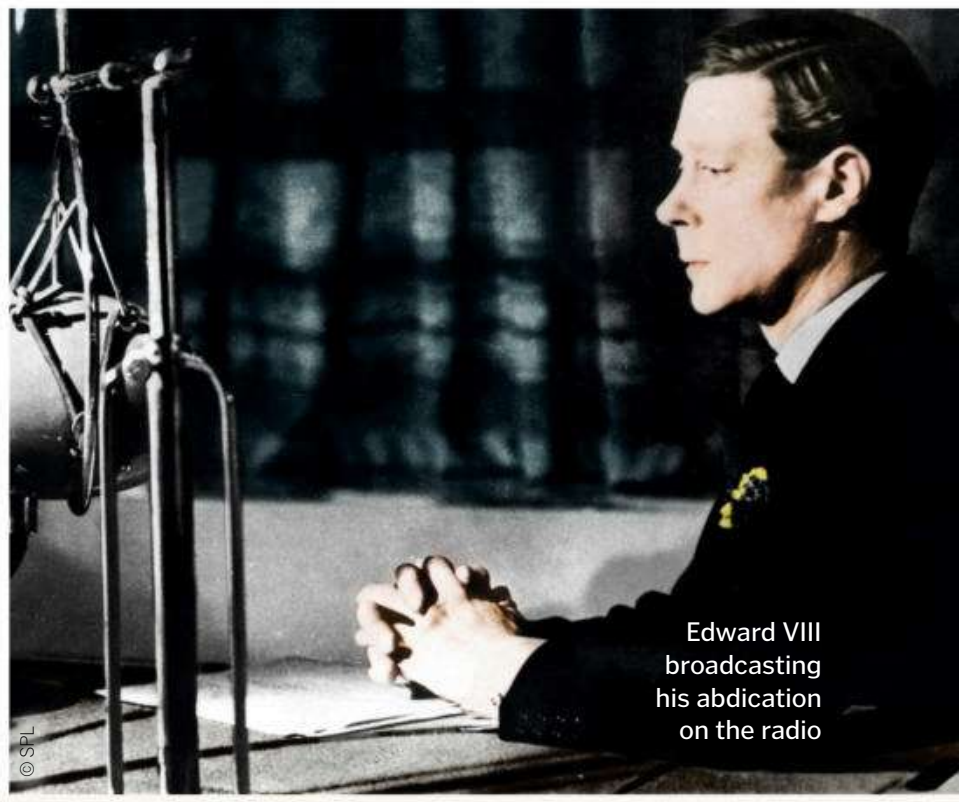
This royal family tree descends from King George VI (1936-1952)

Global monarchies

There are more than 25 monarchies found across the globe, but as the queen of 16 commonwealth countries, Queen Elizabeth II is generally the best known. While connected by the fact they all have a form of royal family, each country has its own rules, with the responsibilities of kings and queens varying. For example, in countries such as Saudi Arabia, if you abdicated as king you would essentially be quitting as prime minister as well. This is because they have an absolute monarchy. Other countries with this system include Brunei, Eswatini, Oman, Saudi Arabia, Vatican City and the United Arab Emirates.

King Salman of Saudi Arabia is both a king and politician

© Getty Images



Edward VIII broadcasting his abdication on the radio

© SPL

1964

Saud *King of Saudi Arabia*
Quit his role after pressure from family to let his younger brother attempt to end the country's financial crisis.

2004

Norodom Sihanouk *King of Cambodia*
Having enough of the royal lifestyle, the Cambodian king retired to become an 'ordinary citizen'.

2006

© Alamy

Jigme Singye Wangchuck *King of Bhutan*
Decided to step down while the country was in 'stability and peace'.

2013

Albert II *King of Belgium*
On Belgium's national day, Albert broke the news of abdication due to old age and ill health.

2014

© Estonian Foreign Ministry

Juan Carlos I *King of Spain*
Feeling he had achieved what he wanted as king and with popularity declining, he passed the title to his son.

Inside the Bank of England

What goes on in the bank's 3.5-acre headquarters?

When you walk down Threadneedle Street in the centre of London, you are effectively walking above a goldmine. The Bank of England is very different from your typical high-street financial institution. This is the UK's national bank, and rather than dealing with digits on a screen, it's partly a storage facility for physical money: bars of pure gold.

Sometimes we love money, yet other times it infuriates us. Some people have too much, and many people not enough. Money isn't everything, but in a world where everything comes with a price, it is something that needs to be managed with serious responsibility.

Most of us will only ever see the outside walls of such a bank, heavily fortified and enclosing a private world. Tasked with managing the economic stability of the UK, its employees and committees meet regularly to manage issues such as inflation rates, currency authenticity and threats to financial stability. It is common knowledge that the thick concrete walls encase a golden headquarters, but what else can be found inside?

The Bank of England was designed by British architect Sir John Soane

Vaults of gold

Storing one of the largest deposits of gold in the world, the Bank of England's vaults are spread across two underground floors. These secure rooms were built in the 1930s and currently hold over 400,000 bars of gold, each weighing around 13 kilograms. When the gold arrives at the bank it has to be sorted and stored. Every bar is weighed and stacked on blue shelves to keep them distributed evenly in number. Each shelf carries 80 bars of solid gold.

This stockpile of gold may be impressive, but as it is no longer used in daily purchases, why do we need to store these hefty blocks underneath the bank? Until the Gold Standard was abandoned in 1931 in the UK, it was so bank notes could represent something. Although people weren't using gold bars to pay, they were still technically the currency. Without the equivalent value of gold held by the Bank of England to cash, this paper money was worthless. The idea was that you could cash in your money for physical gold at any time. Today, you can only exchange a bank note for another note of equivalent value. The gold in the vault is held to support Britain's financial stability.

© Alamy

Keeping gold evenly stored maintains a constant weight and prevents the gold sinking into the floor

© Getty

Within the walls

Take a look inside the ground floor of the most secure building in England

Mould making

Today, modern notes are made of polymer and are more resistant to wear and tear. One element of note-making has been used for centuries and involves incorporating the watermark onto the note. This is done by using a mould and improves security by distinguishing the real notes from any fakes. Bank notes are run through the mould, which has been sewn into the desired pattern. Usually this is a portrait. Fibres used in the mould gather in a higher concentration where the mesh is raised and are more spaced out elsewhere. This gives the picture used as the watermark a unique, three-dimensional effect as it adds shading.

Night watch

With the introduction of CCTV cameras, the entire area can be viewed at any time to analyse any movement inside.

Note office

Ensuring the correct amount of paper money is in circulation, notes are sorted and analysed in a note office. When notes come out of circulation they are destroyed, removing part of the note that holds the signature and serial number. Each number is documented as 'paid' when it has been used. This method has been used since the the Bank of England was founded.

Banknote storage

The Bank of England has to store banknotes that come to the same value of all notes in circulation, as a security measure. Some notes stored for this purpose hold incredible value, much higher than the ones you have stuffed into your wallet. Notes worth a million pounds are called 'Giants' while a hundred million pound notes are known as 'Titans'.

'Titan' and 'Giant' notes are only found in the bank, not in circulation

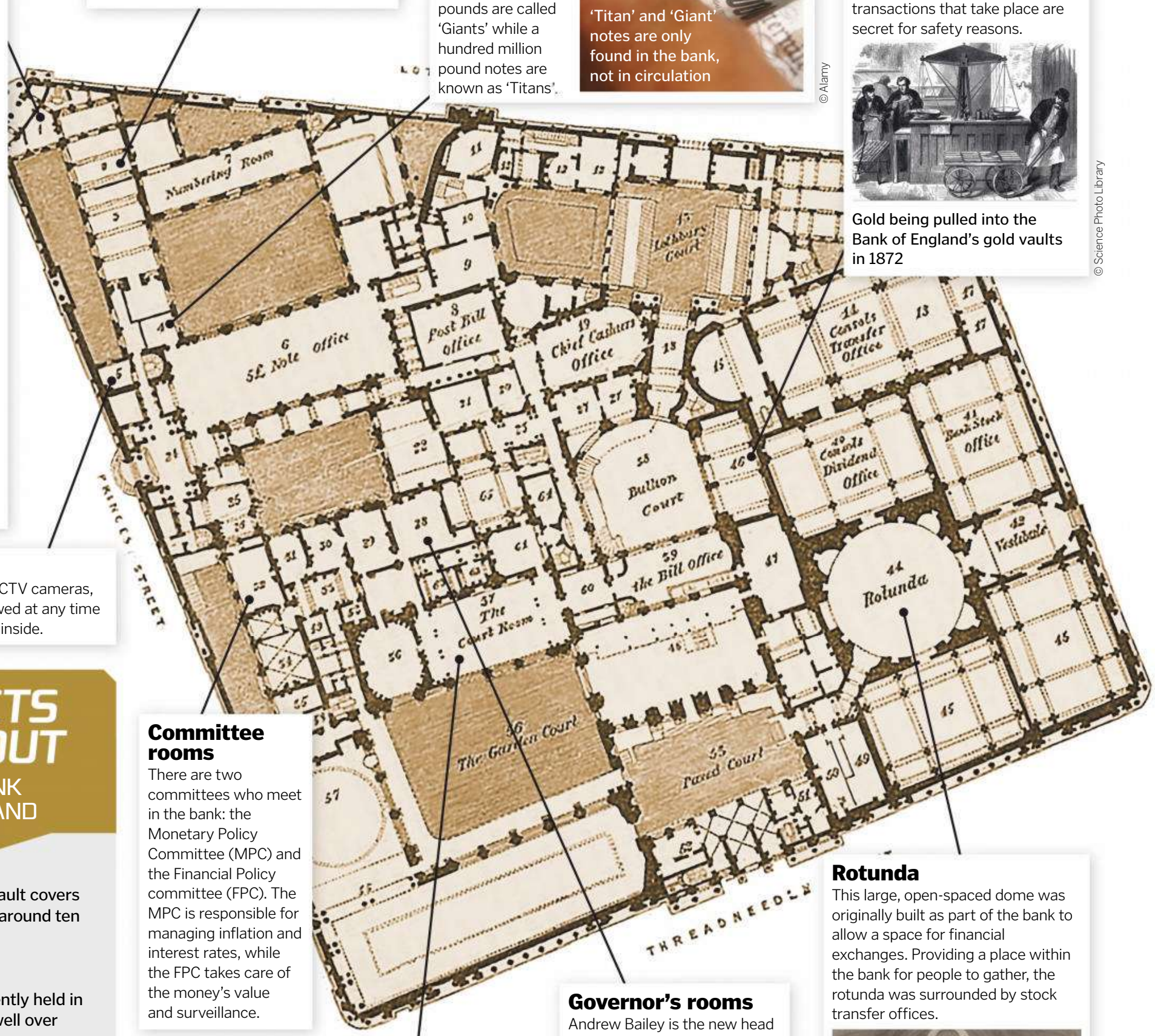
© Alamy

The bullion office

In this area gold bars were sorted, counted and moved onto carts to transport them. Now all the gold is kept underground, and often remains there even after being paid to other countries. The bank stores the gold for over 70 other banks and for 30 countries as well as their own. Any transactions that take place are secret for safety reasons.

Gold being pulled into the Bank of England's gold vaults in 1872

© Science Photo Library

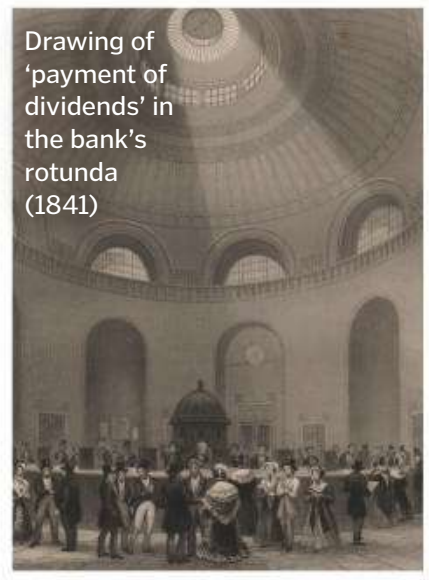


Committee rooms

There are two committees who meet in the bank: the Monetary Policy Committee (MPC) and the Financial Policy committee (FPC). The MPC is responsible for managing inflation and interest rates, while the FPC takes care of the money's value and surveillance.

Rotunda

This large, open-spaced dome was originally built as part of the bank to allow a space for financial exchanges. Providing a place within the bank for people to gather, the rotunda was surrounded by stock transfer offices.



Drawing of 'payment of dividends' in the bank's rotunda (1841)

© Alamy

The court room

This large room was built for the Court of Directors to hold their meetings. These directors determine the bank's key objectives and budgets.

Bank of England court room from 1790

© Alamy

Governor's rooms

Andrew Bailey is the new head of the Bank of England and one of more than 4,000 members of staff in the building. As a top bank official, it's his job to oversee the goings-on inside the bank and play a main role in economic decisions.

Andrew Bailey was made the new bank governor on 17 March 2020

© UK Government

5 FACTS ABOUT THE BANK OF ENGLAND

1 Gold for miles
Gold in the bank's vault covers the equivalent area of around ten football pitches.

2 Storing billions
The contents currently held in the vault is valued at well over £200 billion.

3 Established 1694
The Bank of England is the world's eighth-oldest bank.

4 Past trespasser?
There is a rumour that in 1836 a sewage worker gained access to the gold, but the bank claims never to have been robbed.

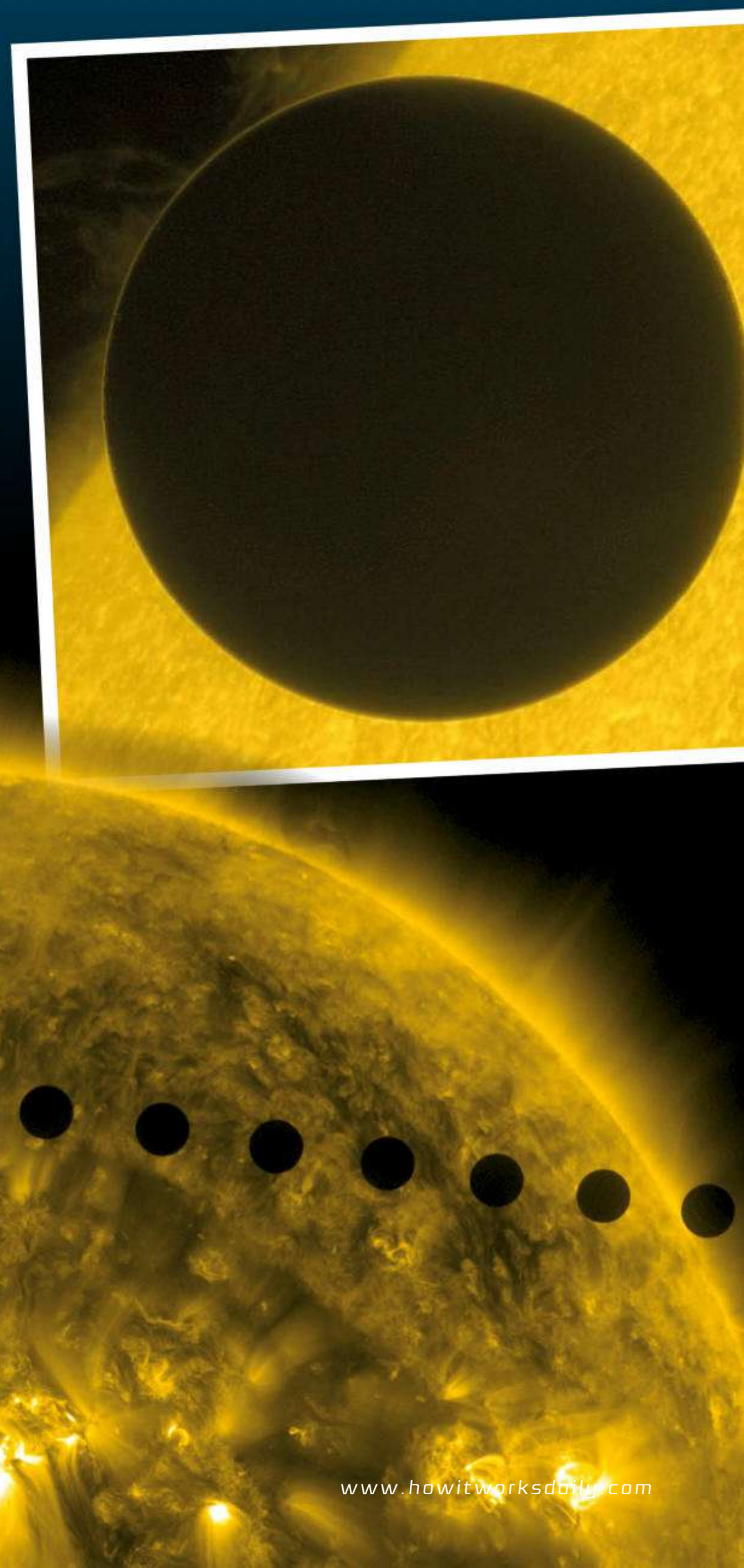
5 Early days
When the bank first opened its doors, it was staffed by 17 clerks and two gatekeepers.

Amazing astrophotography

How these incredible space photos were taken and what these wonders are

Words by **Ailsa Harvey**

Other than producing stunning otherworldly displays of intricate shapes and fiery colours, space photography has become essential in our attempts at understanding the universe. Since the first astronomical photo was taken of the Moon in 1840, technology has advanced to give us the clearest and most accurate representations of the universe and its contents. Wide-field cameras enable us to shoot an extended area, while capturing obejcts in infrared, X-ray and other wavelenghts lets our eyes absorb the fine details of explosions, collisions and other cosmic events. How It Works explains how some of our favourite space images were taken, allowing us to take in scenes from millions of light years away.



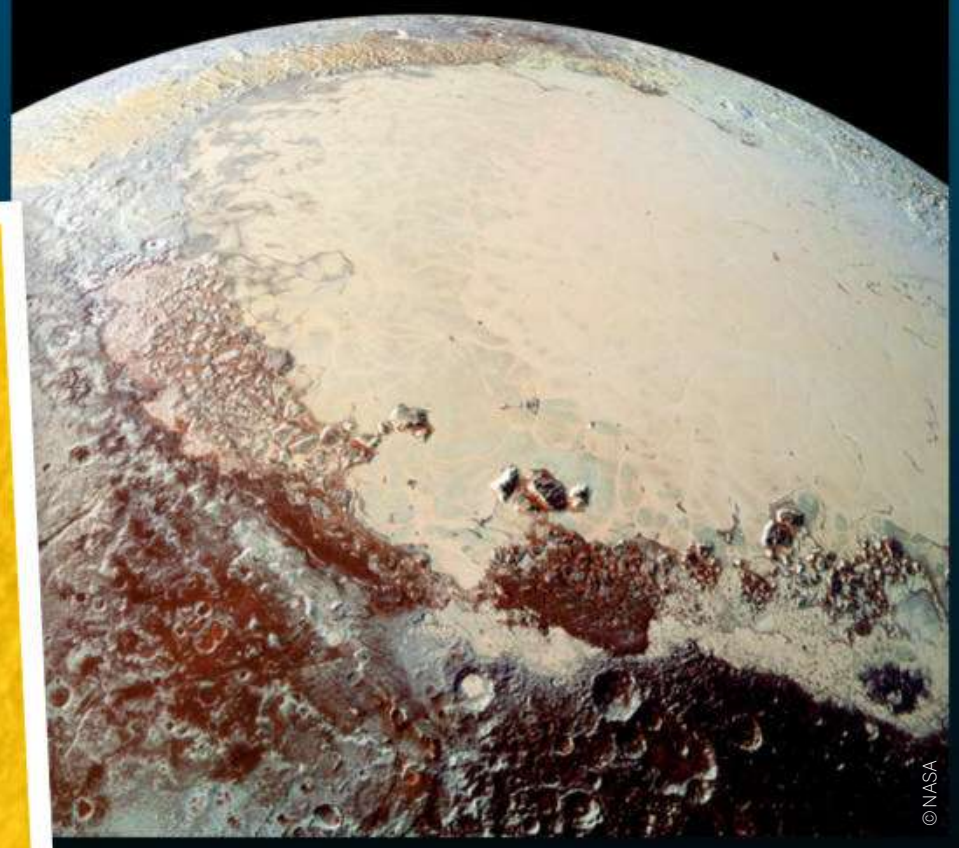
VENUS TRANSIT

In this picture, a time-lapse composite of multiple images, Venus can be seen moving across the Sun. Not only is the image an impressive spectacle, but the occasion itself is a rarity. It repeats in a pattern every 243 years and the next time this can be seen will be in 2117. Meanwhile the close-up photograph, taken by the Japanese Hinode's Solar Optical Telescope, shows wispy detail at the Sun's surface. The contrast of the nightside of Venus as a small, black disc across the mighty, bright Sun gives this image the ultimate dramatic impact.

© NASA/Goddard/SDO and JAXA/NASA/Hinode

APPROACHING PLUTO

In the closest-ever encounter with Pluto, 12,500 kilometres above the surface, this image was taken by NASA's New Horizons spacecraft. Its cameras were able to zoom in to show us the most detailed view we have of Pluto's surface. The terrain could be compared to some of the rocky landscapes found on Earth, as mountains seen in this image reach as high as 3,500 metres. Looking closely at the pale areas in shot, slabs of methane ice add to the dwarf planet's snakeskin appearance.

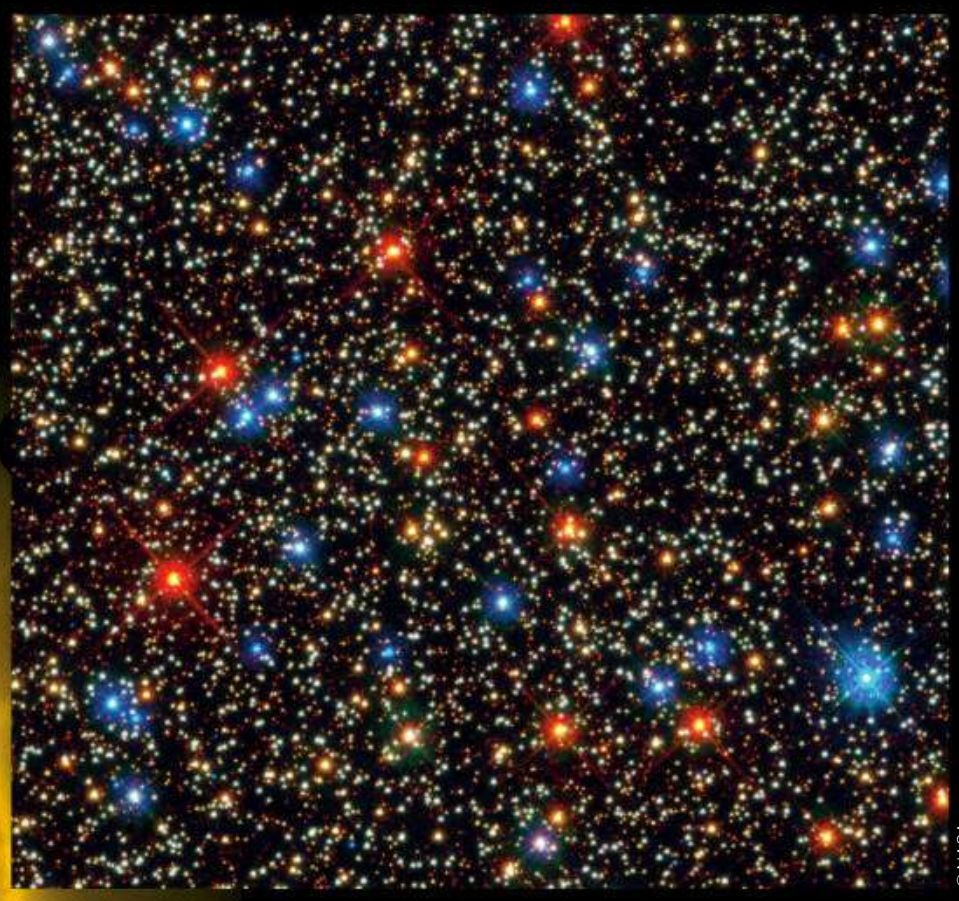


© NASA

COLOUR CLUSTER

It's not often you get to see 100,000 stars in one place. But in this photograph, taken by the Hubble Telescope's Wide Field Camera 3, they come together in a striking panoramic assortment of reds, oranges and blues. What you are looking at here is a section of the Omega Centauri star cluster – home to 10 million stars. Aged between 10 and 12 billion years old, they shine 16,000 light years away from us.

The colour diversity signifies the different stages of life the stars are in: yellow-white dots show stars at the stage of hydrogen fusion – the stage that our Sun is currently in – the orange dots are older stars that are cooler and larger in the sky, red dots are red giants while the blue dots are nearing the end of their lives, their hydrogen exhausted, the stars now fusing helium to emit most of their light in ultraviolet wavelengths. Some stars appear to be almost touching, though the distance between any two stars in the image is about a third of a light year. If Earth was placed within this star cluster, our night skies would be about 100 times brighter.



© NASA

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HUBBLE'S BUBBLE

Taken in 2016, Hubble's first image of a complete nebula showed a balloon bursting with colour in astonishing detail. This image was the third attempt at a photo; the first suffered from blurriness and the second didn't have a wide enough field of view. However, the end result was definitely worth the wait.

The bright star seen inside the bubble, slightly left of the image centre, is creating this immense sphere. Using its strong winds of radiation, the star, which is betwween ten and 20 times the mass of our Sun, blows the surrounding clouds of space dust outwards around it. This bubble is heated by radiation, producing this sphere of contrasting colour.

© NASA/JPL-Caltech/STScI/Vassar

EYES IN THE SKY

When galaxies collide, they sometimes merge into one supergalaxy, in the case of these two galaxies creating a pair of eyes in the sky. NGC 2207 and IC 2163 have been together for around 40 million years. Grappling with each other as huge gravitational forces act on the star systems within, these two galactic eyes will one day combine into a single large eye.

The reds and greens incorporated into this image resemble a mask that could belong to some sort of supervillain, but this colour scheme is the work of two telescopes. NASA's Spitzer Space Telescope contributed the infrared data forming the majority of the red, while visible data from NASA/ESA's Hubble Space Telescope captured the blues and greens.

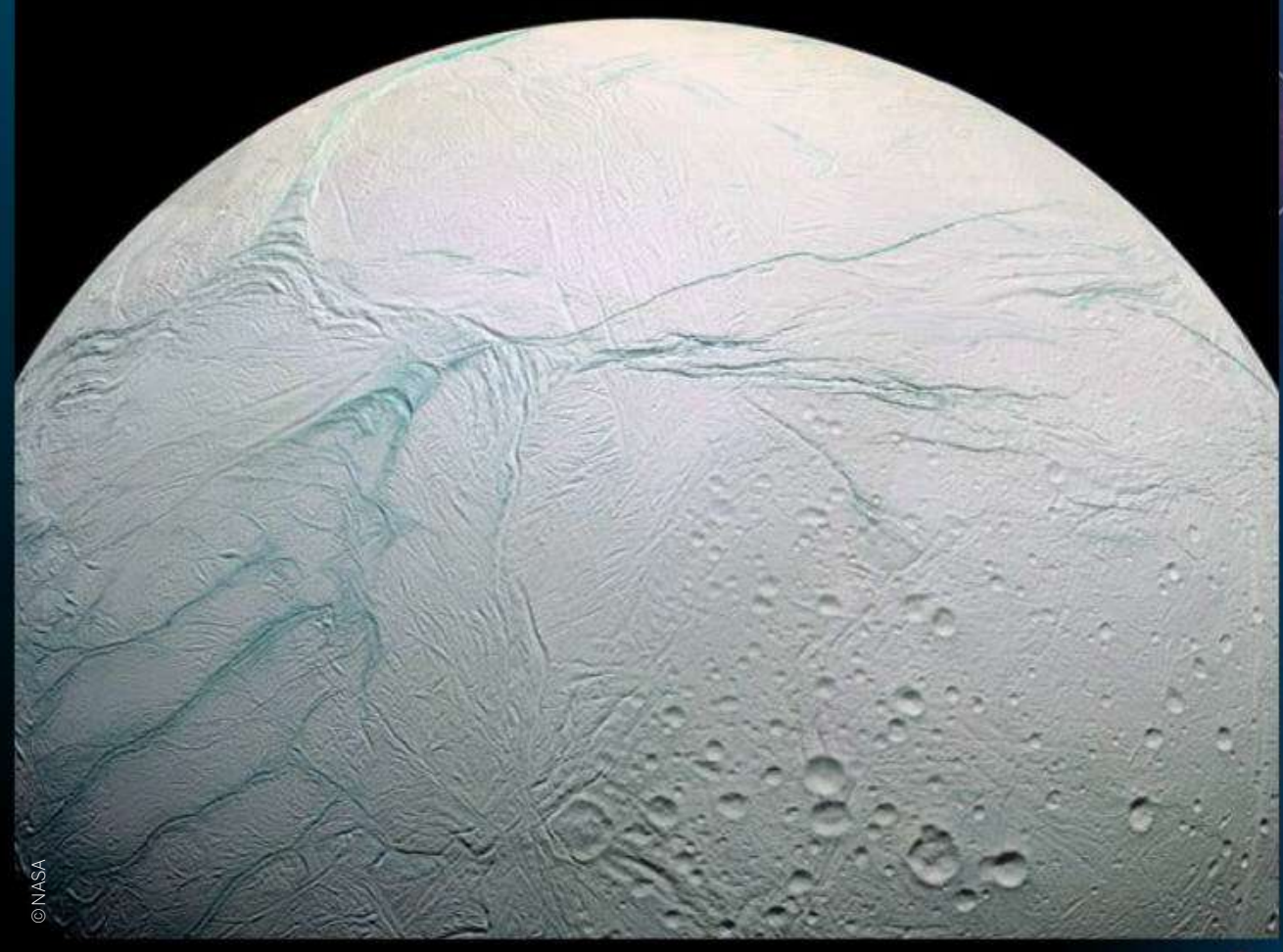
© NASA (NASA/CXC/Wesleyan Univ./R.Kilgard/STScI)

GALACTIC GLITTER

Messier 51, otherwise known as the Whirlpool Galaxy, forms a spectacular spiral. As a galaxy similar in shape to the Milky Way, it sitting face-on to Earth helps us to understand the formation of our own galactic home. NASA's Chandra X-ray Observatory imagery, shown in purple, combines with optical imagery from the Hubble Space Telescope, shown as the red and blue areas, to create a delightfully detailed depiction of this stellar swirl.

STRIPED MOON

The icy surface of Saturn's moon Enceladus is covered with huge geysers. At its south pole they erupt through the icy crust, creating features referred to as 'tiger stripes' by scientists. The stripes are parallel to each other and are often evenly spaced. Shot in their distinguishable blue, these cracks are continuously erupting with water ice. A combination of the moon's atmosphere, a thin south pole crust and deformation caused by the gravitational pull of Saturn creates this decorative pattern. Photographs taken of Enceladus are unique because there are no other known moons or icy planets with features like them.



© NASA

SOMBRERO GALAXY

The flat disc in the sky that forms the Sombrero Galaxy is captured in detail so fine that scientists have not yet pieced together an understanding of its full composition.
Like a frisbee caught in the abyss, this image makes the galaxy appear thin and fragile. However, with a mass 800 billion times that of the Sun, it is one of the largest known objects. Deep in the centre there is thought to be a large black hole surrounded by 2,000 globular clusters; this is ten times as many of those found in our own Milky Way.

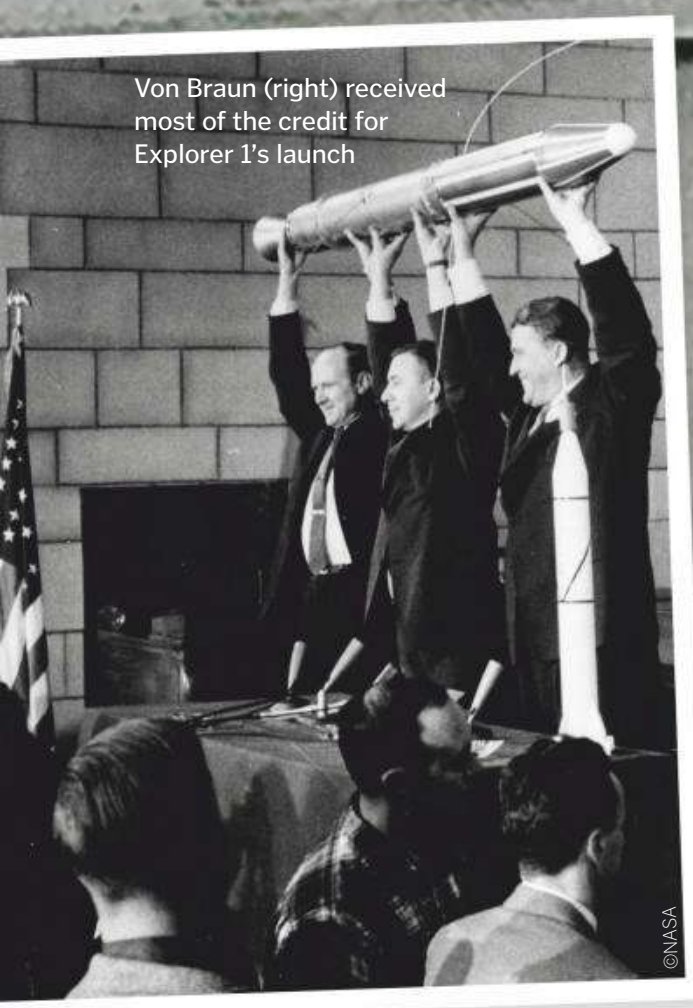
© NASA/ Hubble Heritage team

PILLARS OF CREATION

Like an abstract castle in the sky, this distinctive image of dense interstellar gas and dust captures the creation of new stars. This photograph, which was taken by the Hubble Space Telescope, shows space matter 6,500 light years away from Earth. The towering verticals, formed in the Eagle Nebula, are shaped by stellar winds from other nearby stars. The production of this shot wasn't as simple as a well-timed snap. Astronomers Jeff Hester and Paul Scowen artfully composed the original image in 1995 by combining 32 separate images from four different cameras. This 2015 version, taken by the Hubble Space Telescope, shows glowing oxgen, hydrogen and sulphur.

© Alamy

Without Morgan's efforts, the US would have fallen further behind in the Space Race



Von Braun (right) received most of the credit for Explorer 1's launch

©NASA

©Wikimedia Commons George Morgan

A life's work

Morgan's path to saving the US space programme

1921
Mary Sherman was born in Ray, North Dakota, on 4 November 1921.

1939
Mary ran away from home to attend Minot State University as a chemistry major.

1939
Mary graduated high school, becoming class valedictorian.

1940s
Postponing her degree, Mary was offered a top-secret position at Plum Brook Ordnance Works, manufacturing explosives.

Mary Sherman Morgan

Words by **Nikole Robinson**

Discover how the first female rocket scientist secretly influenced the international Space Race

Due to her humility and the top-secret nature of her work, Mary's accomplishments only came to light when her son, George, was told her obituary could not be verified. He made it his mission to publicise what she had made possible, highlighting her role as the saviour of the US in its space-faring struggles.

Born on her family's farm in Ray, North Dakota, Mary was kept out of school so she could help her father with farm work. The authorities soon intervened, and she was sent to attend the small-town schoolhouse. Being a few years behind didn't hold her back, and by the time she graduated high school, she represented her class as valedictorian. Aware of her intelligence, she ran away from Ray to attend Minot State University as a chemistry major, where her skill was evident.

The outbreak of World War II resulted in a national shortage of chemists and scientists. In spite of the fact she was still a student – and a woman – due to her talents she was offered a job as a chemical analyst with Plum Brook Ordnance Works, producing explosives for the wartime effort. She put her degree on hold and moved to Ohio, taking on the dangerous job of analysing volatile chemicals to produce weaponry.

After the war ended there was a fall in demand for explosives, so she made a move to the field of aeronautics, moving to California to work for NAA (North American Aviation). The only woman out of 900 engineers, she was soon promoted to a role which involved calculating the performance of rocket propellants and designing specialty fuels to work with different engines. However, having never returned to complete her degree, she was not afforded the rank or higher pay of an engineer, even though she boasted all the skills and knowledge of one.

Her experience with propellants meant that when NAA was tasked with solving problems with rocket fuel, Morgan was appointed technical lead on the project. She needed to find a fuel capable of lifting redesigned Redstone rockets into space. National pride was on the line, so Morgan set about investigating fuels, finding several insufficient or incompatible before finally designing her own mixture, which was named Hydyne.

> *"She needed to find a fuel capable of lifting the redesigned Redstone rockets into space, and soon"*

Hydyne tested well with Redstone missiles, and subsequently Jupiter-C rockets, proving to be a quick solution to get to space without a total rocket redesign. The fuel made the first successful US satellite launch possible, even if Morgan silently slipped away from her success, retiring to focus on her family, leaving her chemistry career behind.

THE BIG IDEA

How her Hydyne fuel saved the US in the Space Race

With the launch of Sputnik in 1957, the US was in crisis. It needed to launch a satellite into space, but had no fuel powerful enough to launch the heavy Redstone-derived rocket, and the need for more fuel would only increase this weight. With Wernher von Braun and other top engineers unable to find a solution, the problem was outsourced to North American Aviation's Rocketdyne Division. Morgan was named technical lead on the project due to her expertise, and her work resulted in a new propellant, Hydyne. 60 per cent unsymmetrical dimethylhydrazine and 40 per cent diethylenetriamine, Hydyne provided the boost needed for the US to get off the ground, putting Explorer 1 into orbit and the country back on even footing in the Space Race.

Explorer 1 was the first spacecraft to detect the Van Allen radiation belt around the Earth

FIVE LEGENDS ABOUT... MARY SHERMAN MORGAN

1 Helping horse
Mary was supposedly given a horse to help her make the journey to school as a child after her parents were told she had to start attending.

2 First child
In 1943 she fell pregnant out of wedlock, seen as shameful in the 1940s. She gave the child up to her cousin Mary Hibbard and her husband Irving.

3 Bagel and LOX
Morgan suggested the name bagel for her fuel, a play on liquid oxygen and a brined salmon called Lox, which was paired with bagels.

4 Credit checker
Hydyne has been falsely credited to Morgan's supervisor at North American Aviation, Jack Silverman, and also Irving Kanarek.

5 Best at bridge
After her retirement Morgan played the card game bridge often, winning several tournaments. She would play herself obsessively at home.

29 July 1951
Mary married Richard Morgan, a co-worker and mechanical engineering graduate from the California Institute of Technology.

1947
Mary applied for a job with North American Aviation. She was shortly promoted to theoretical performance specialist, working with rocket propellants.

1955
Mary, pregnant with their second child, announced her retirement from NAA to focus on her family.

1956
The first Hydyne-powered research and development testing of Redstone rockets.

1 February 1958
Explorer 1 is launched on Juno I, derived from the Jupiter-C rocket, only possible because of Hydyne.

2004
Mary, a smoker throughout her life, died of emphysema on 4 August 2004.

©NASA

250mph SUPERFAST TRAINS

Discover the levitating vehicles on track to become one of the fastest forms of public transport in the world

Words by **Ailsa Harvey**

Since the first train was built in the early 19th century, engineers have focused on ways to make this method of transport bigger, better and, most importantly, faster. With trains operating around the world at speeds that could only be imagined in the early days of public transport, rapid travel has become the norm in today's world. And with new speed records with every new generation of train, technology is advancing to bring us to our destinations in much less time. Why spend hours sitting and staring out the window if it isn't necessary after all.

Enabling people to cover ground at super speeds, fast trains are opening up new ways to travel between cities as the world becomes more connected than ever before. When the very first steam trains were introduced to the world, these ten-mile-per-hour vehicles were considered marvels, transforming the ways of transporting both materials and people. Today, hopping on board a high-speed rail, the same journey could be completed up to 30-times faster.

Bullet trains are found mainly in Asia and Europe and are extremely fast and futuristic-looking. While they are currently dominating the world of train travel, soon journeys could be so fast they might feel like stepping into a teleportation machine. Entering tubes instead of taking your place on a crowded platform, soon we could be shuttled hundreds of miles as extreme forces transport us across the ground faster than any other land vehicle.

© Getty

Staff work on bullet trains at Qingdao manufacturing line, China

THE WORLD'S FASTEST TRAINS

© Getty

Shanghai maglev

Shanghai (China)

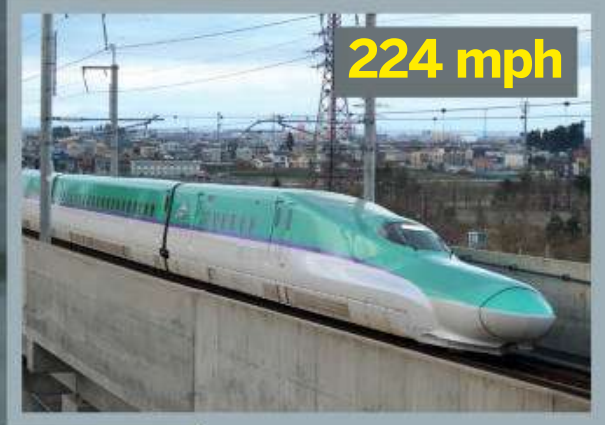
Having been in operation since 2004, this train shuttles passengers to and from Pudong International Airport every 15 to 20 minutes. The journey covers a distance of 19 miles in an impressive eight minutes or less.

© Getty

Fuxing Hao

Beijing to Shanghai (China)

China continues to speed into the lead with its longer distance train. Translated to English, Fuxing means 'renaissance', and the train symbolises a positive future for China's advanced technology.



© Getty

Shinkansen H5 & E5

Tohoku to Hokkaido (Japan)

Japan's superfast trains are some of the most regular. The bullet trains are improved, speedier versions of the country's first high-speed system in 1964, and its citizens continue to access Japan's cities in record times.

Source: Wiki/XXXXXX

Italo and Frecciarossa

Milan to Florence/Rome (Italy)

If the impressive top speed isn't enough, this train is built using almost entirely renewable and sustainable components. Journeys from Milan to either Florence or Rome are completed in less than three hours.

© Alamy

Jingzhang intercity

Beijing and Zhangjiakou (China)

China can boast of having the world's fastest driverless train, with one of the top speeds among trains around the world. Originally this train was built to improve transport as China hosts the 2022 Winter Olympic Games.

TRAINS OF TOMORROW

How will high-speed hyperloop technology carry passengers at speeds over 700 miles per hour?

Compressor fan
A large fan covers the front of the train, sucking air from the tube in front and redirecting it to the back.

Moving air
As air is pushed back through the tube, air resistance on the moving train is reduced.

Individual sections
Trains will be split into small capsules, linked together to form a train. Being separate helps the structure absorb shock from earthquakes more safely.

Levitation support
Air is pumped out through small holes in the bottom of the pod, keeping the base cushioned as it hovers above the tube's floor during transportation.

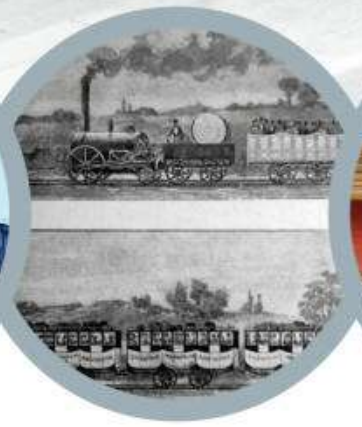
CHUGGING ALONG

1804
Richard Trevithick is credited with inventing the first train: the Pen-y-darren steam locomotive.

© Getty

1825
'Locomotion' was the first steam train to travel at 15mph, all while pulling 36 wagons full of coal and flour.

Source: Wiki/XXXX



1830
George Stephenson built the first steam train to work as an intercity link, between Liverpool and Manchester.

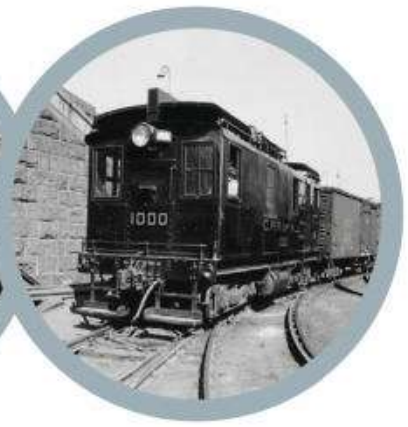
Source: Wiki/XXXX

1879
The first electric railway. Werner von Siemens' train carried 90,000 on a circular track over four months.

Source: Wiki/XXXX

1881
Following the success of using electricity, Siemens founded the first electric tram line.

Source: Wiki/XXXX



1892
Rudolf Diesel's diesel engine patent became the starting point for combustion engines in trains.

Source: Wiki/XXXX

Reducing drag
Being encased inside a low-pressure tube – similar to a vacuum – eliminates the resistance experienced on trains running out in the open.

Sustainable electricity
Hyperloops could be fitted with solar panels above the tube to create electricity. With less friction to combat, higher speeds can be created using less power.

© Science Photo Library

Protective tube
Encapsulated in a tube, the structure enables routes to take passengers both above and below ground.

Suspended travel
Balanced by the magnetic forces, when travelling in the tube the passengers' capsule is floating in the gap.

Magnetic system
Electromagnets fitted around the side of the train pods are attracted to magnets inside the tube, creating the initial pull movement along the tube.

© Getty

Japan's Shinkansen train passes the famous Mount Fuji

Bullet vs hyperloop

In terms of maximum speed, the vacuumed tube of the hyperloop definitely wins. One thing the two share is their magnetic levitation. The high speed is down to friction reduction, and sending people hovering just above ground via electromagnetic attraction appears to be the best way.

When you hold opposite magnetic poles near each other they attract each other, while the same charges repel. Maglev trains use strong magnets to raise the carriages above the tracks. There are two types of maglev trains: those that use attraction forces and those that use repelling forces.

While maglev works in both of these to remove the friction of wheels, bullet trains are significantly slower due to air resistance. Not only is speed less compromised, but being encased in a tunnel gives hyperloops the potential to be built underground in an efficient straight line.

Hyperloop technology has an estimated cost of at least $6 billion

© Neuhausen Group

1950s
Diesel-electric engines rose above other methods, with diesel engines driving an electric generator.

Source: Wiki/XXXX

2000s
With the introduction of magnetic levitation, trains demonstrated a level of efficiency far beyond diesel.

Source: Wiki/XXXX

Post-2020
Hyperloop trains are being tested as our search for the fastest and most efficient travel continues.

© Alamy

Creating a drone superhighway

How will these autonomous vehicles take to the skies?

In a future that's creeping ever closer, 21st-century technology will drive the smallest of everyday tasks. As the demand for drone applications rises, they could soon swarm across large stretches of the sky, delivering goods, monitoring the air quality and acting as surveillance systems to keep us all in check.

Not only could a highway in the sky help companies expand their business, it could also help control casual drone-fliers. Putting more rules on the occupation of airspace could force hobbyists to carry out their drone flying using safer equipment and make them more respectful of boundaries.

One common idea – shared by Amazon, NASA and Google – is to create lanes in the sky: a superhighway for aircraft of different speeds and classifications. This would stop drones being flown at heights occupied by commercial planes or near airports. When Amazon announced Prime Air – a new way to deliver online orders using drones – it was hard to imagine the details. How could each individual parcel be flown exclusively through the air, rather than in the safety of the postman's satchel? However, with a framework already in place, Amazon's proposed drone superhighway shows the sort of structure that could allow for an updated postal network. So how will drones avoid airborne obstacles to transform the infrastructure of industries usually found on the ground?

Safer flying

Accidents have already shown the dangers uncrewed drones can cause by sharing the sky with larger, crewed aircraft. With this in mind, planners have realised communication between them is key. Being able to sense and avoid other obstacles using radio waves, drones can automatically move away from danger.

Drones need to react with the same efficiency a pilot would to avoid collisions, otherwise the superhighway system is a road to disaster. Some forms of sense-and-avoid technology create alerts which are sent to the ground for an operator to take action, but the best form of this radar technology is when vehicles sense other vehicles or objects in the sky and respond automatically. Not only is this quicker, but more effective for mass-scale drone flying.

© Alamy

Drones equipped with detection technology would allow others to fly in closer proximity

Traffic management

How urban airspace could be safely split into lanes

Integrated airspace

Above the drone-oriented lanes lie a mixture of aircraft varieties. At greater heights commercial aeroplanes fly in drone-free zones beyond the no-fly zone.

No-fly zone

Altitudes from 120 to 150 metres are forbidden for flying drones. This gives larger aircraft confidence that they won't encounter small drones when flying in this area.

High-speed transit

The highest drones can fly in this superhighway proposal is 120 metres. Primarily this area is for those carrying out long-distance deliveries, and the speed they fly at will be much greater than those in the regions below.

Drones with jobs

Over urban areas, increasing the volume of drones safely utilising the sky also broadens the number of roles they can play in a community's lives. These include local weather forecasting, security and surveillance, town planning and speedy delivery of supplies in emergencies.

Takeoff and landing

As one of the most complicated and crucial parts of any aircraft's journey, traffic-management systems could focus on smooth ascents and descents by allowing time between takeoffs in allocated areas of cities.

Low-speed localised traffic

This is the slow lane, including altitudes below 60 metres. Any local drones carrying out business in the area can use this section and need to abide by the safer speed limit.

© Getty

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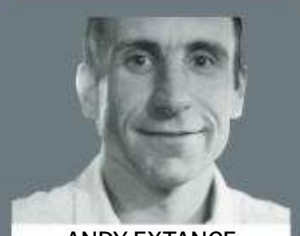
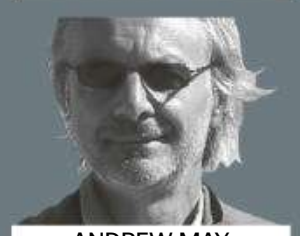
MARK SMITH


ANDY EXTANCE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AMY GRISDALE

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Why aren't blue whales more intelligent than humans if their brains are so big?

Kevin Machin

A blue whale's brain is around five-times bigger than a human's. However, a blue whale's brain only accounts for about 0.007 per cent of its total body weight. Human brains account for 0.02 per cent of their total body mass, making them proportionally 286-times larger than a blue whale's, and have many more complex folds and neural pathways than a simple blue whale brain. **AG**

© Getty

Could vaccinations have stopped the spread of plague in medieval times?

Ros Denton

The deadly plague that killed a third of Europe was caused by a bacteria called *Yersinia pestis*. If the people of the 1300s had today's technology they could indeed have created a vaccine. Scientists today have developed vaccinations against several strains of the Black Death. Lab trials of this vaccine had a success rate of 80 to 100 per cent. You might think developing a plague vaccine now is too little too late, but having a treatment ready could prevent another widespread outbreak. Plague hasn't been eradicated completely. Up to 3,000 people a year contract it to this day. **AG**

Scientists modified plague bacteria to trigger an immune response rather than causing disease

© Getty

© Getty

Are there still undiscovered elements?

Alice Harrison

Scientists think so, but are struggling to find anything beyond the 118 we already know about. Any new element would probably only exist for a tiny fraction of a second. **AE**

Our brains are sorting, storing and 'deleting' memories while we're deep in slumber

© Getty

Why do we only remember some dreams?

Tim Waddington

We might be more likely to remember a dream if we wake up while it's still happening. There's evidence that our memory centres store memories of emotionally charged dreams. Scientists think dreaming gives us a chance to get rid of excess information the brain has taken in during the day. This would explain why we dream about things we've seen or heard lately and why we don't remember all of them. **AG**

What's the difference between the chemical structures of jam and jelly?

Stephanie Black

There are a lot of different chemicals in both! In the UK, jelly refers to the wobbly deserts made with gelatine. Gelatine is made from a protein called collagen taken from animals, which helps to make their skin firm, so isn't suitable for vegetarians. Jam is mostly just fruit and sugar. **AE**

© Getty

BRAIN DUMP

Australian skies glow an eerie orange as the fires rage on

© Getty

Are Australian wildfires becoming more frequent?

Noah Smith

Australian wildfires are definitely on the rise and will become even more frequent in the future. Recent studies have discovered that this worrying trend is mainly due to climate change rather than natural variation and will therefore continue to increase in frequency as the planet continues to heat up. The climate crisis has, not only raised temperatures to over 40 degrees Celsius in Australia, it has also changed rainfall patterns, leading to inevitable droughts. **JE**

Balloons can't escape into space, but the helium inside might

© Getty

Does the helium gas in balloons float up into space?

Joyce Lawrence

While helium in balloons does get lost, it doesn't exactly float into space. It is light enough to drift to the upper atmosphere. Helium wouldn't get into space on its own if it leaked from a balloon, but the Sun shoots out particles that churn up the upper atmosphere. This can rip out some helium into space. While this doesn't happen to most helium, it's still nearly impossible to retrieve it out of the air. **AE**

© Getty

Why is petrol so cheap in the US compared to UK?

Mason Carter

It's all down to taxation. Federal tax on petrol is about 18 cents a gallon in the US, while in the UK, two-thirds of the petrol price consists of fuel duty and VAT. **JE**

What difference do cars make to global warming?

Yuumi Fujimoto

The average car emits 5,450 kilograms of carbon dioxide every year. More carbon means more heat trapped in our atmosphere, so using motor vehicles contributes to global warming. **AG**

© Getty

© Getty

Why can motorcyclists turn just by leaning to one side?

Enric Porras

You can't actually turn a bike by leaning, only by turning the handlebars. But riders must maintain a bike's centre of gravity to keep it stable during a turn, and they do this by leaning. At low speeds you don't notice the lean, but at faster speeds you do. **MS**

How do banks profit from storing your money in an account?

Anya Petrov

Banks take the money that you have deposited, offering you interest to keep you saving at their establishment. Meanwhile, they offer your money out as loans to other clients at a much higher rate of interest, thereby making a profit even after paying you your yearly interest. **JE**

© Getty

How do they make the glass in car windows 'shatterproof'?

Heather Porter

Most car windows are a bit like a see-through sandwich. Between two layers of glass is a filling of plastic, made sticky by heating it in a very hot oven under high pressure. When one of the outer glass layers breaks, it stays stuck to the filling. That means people can still see through the window. But you can make windows even tougher by changing what they are made of. Glass is mostly a mixture of the elements silicon and oxygen, known as silicate. But switching silicon for carbon can produce polycarbonate plastics, which make tough and see-through windows. **AE**

© Getty

Glass in car windows doesn't shatter because it's like a sandwich with a sticky filling

BRAIN DUMP

How are buildings made earthquake proof?

George Hayes

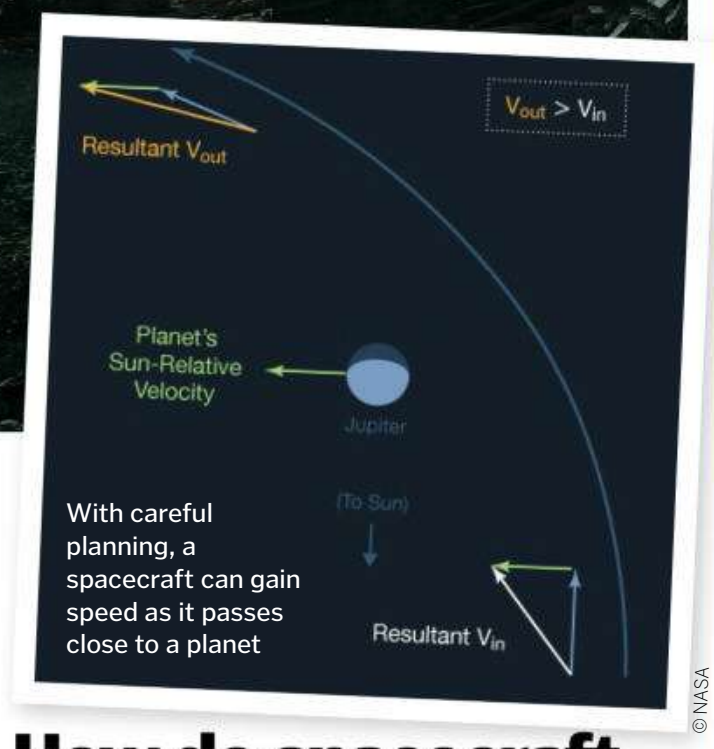
Sadly we can't make buildings quakeproof just yet, only shock resistant. Now, while buildings are designed to hold weight from top to bottom, they're not supposed to feel pressure from the sides. But an earthquake does exactly that – its shock waves 'push' the building sideways – so the key to staying intact is finding a way to keep a building stable even if the ground around it moves. One technique engineers use is to build their foundations on a layer of shock absorbers like ball bearings, padded cylinders and springs. When the shock wave pushes the ground sideways the absorbers take the hit while the building stays pointing upright. **MS**

© Getty

When did humans stop living in caves and start building houses?

Safi Boulous

Early humans were never cave dwellers since they led nomadic lives and therefore slept in the open – so there's actually no such thing as a caveman! They may have sheltered from storms but would never have set up home in such a place. However, during the Palaeolithic era people started to build temporary camps out of hazel bent over in a circle, which was then covered in animal hides. By the early Neolithic period, humans began to build timber halls. During the Bronze Age homes were constructed with the dry-stone walls and thatched roofs that we would recognise as 'houses' today. **JE**



With careful planning, a spacecraft can gain speed as it passes close to a planet

© NASA

How do spacecraft like Voyager travel so much faster than terrestrial aeroplanes?

Brandon Fields

For one thing, a rocket can accelerate to much higher speeds in space because there's no air resistance. Then, when the spacecraft leaves Earth orbit, the speed it's acquired relative to Earth is supplemented by Earth's own enormous speed around the Sun, which the spacecraft gets to keep 'for free'. If the mission planners are clever enough, spacecraft can acquire additional 'free' boosts via gravity-assist manoeuvres – slingshot-like effects when passing close to other planets. **AM**

© Getty

Orbeez can grow up to 150 times in diameter when they're placed in water

How do Orbeez grow?

Danielle Walters

Orbeez can increase their diameter an amazing 150 times over, allowing them to grow to around 14 millimetres. But it's not magic – it's all about how they're made. They're composed of a super-absorbent polymer made of acrylic acid, sodium hydroxide and water, with a colour pigmentation added to make them stand out from each other. When you put them in warm or hot water they absorb the water and get bigger and bigger. **MS**

Will quantum computers be able to hack bitcoin?

Vishal Jain

Maybe in the future. A team of researchers recently claimed quantum computers could crack it (allowing access to Bitcoin wallets), but they won't become sophisticated enough until around ten years from now. **MS**

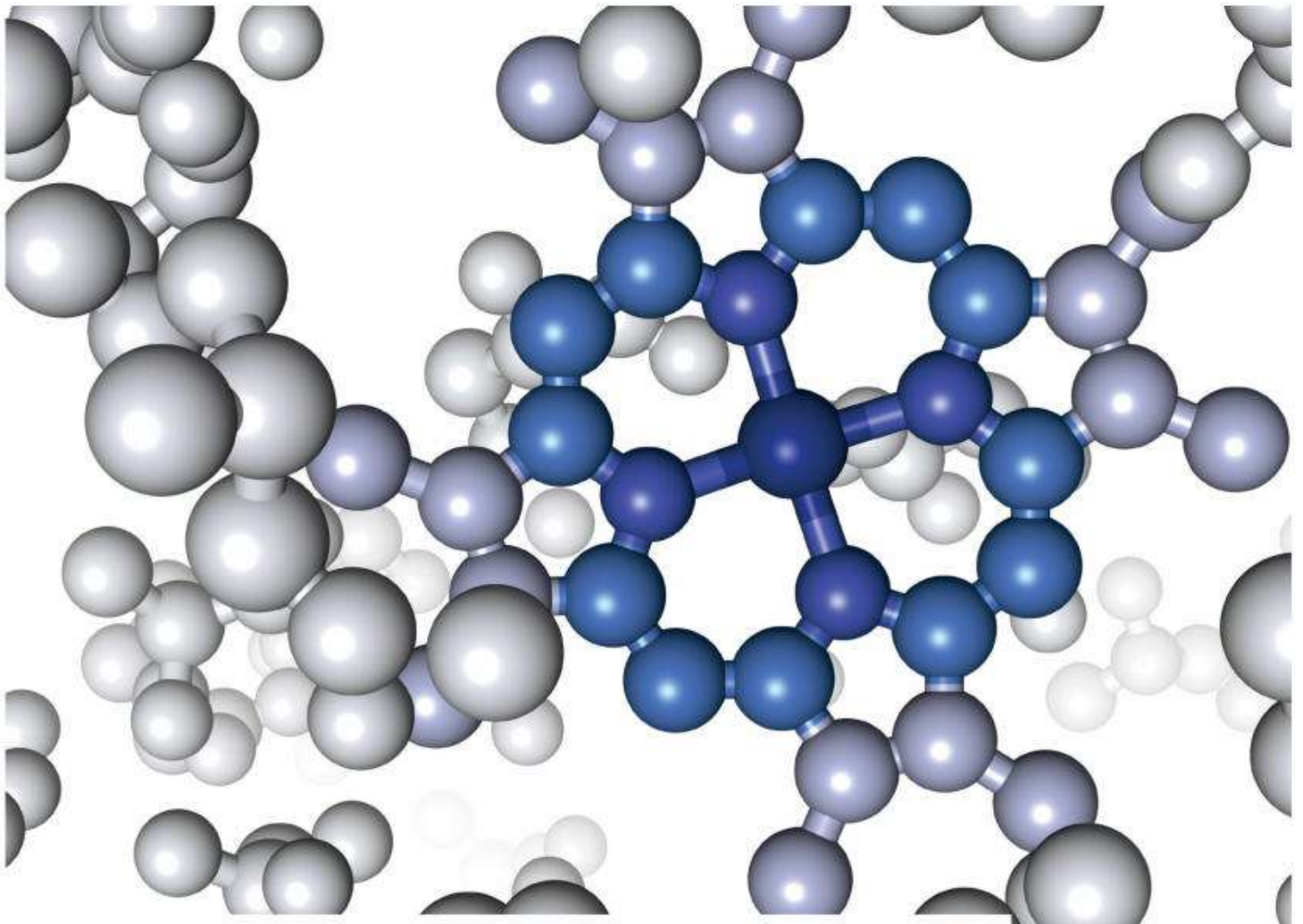
© Getty

What is a CCD and why is it so important?

Gwen Morgan

A charge-coupled device (CCD) is an image sensor similar to a digital camera's CMOS sensor, but is much better at imaging very faint objects. This makes CCDs ideal for astronomical applications. **AM**

© NASA



© Getty

Why can't anything get colder than absolute zero (-273.15°C)?

Julia West

At a microscopic level, temperature is a measure of the average energy of atoms and molecules. At absolute zero they are all in the 'ground state' – the lowest possible energy that quantum physics allows them to reach. **AM**

Vapour trail from the massive space rock that crashed to Earth near Chelyabinsk in 2013

Has a huge meteorite ever been recorded hitting the Earth?

Liana Chalupka

It depends what you mean by 'hitting the Earth', because most space rocks entering the Earth's atmosphere break up into small fragments, or vaporise completely, before they reach the ground. The biggest impact that was literally recorded, in numerous videos, happened in 2013 over Chelyabinsk in Russia. Before it broke up that object was around 12,000 tonnes – huge by any standards – but the largest surviving fragment is a mere 654 kilograms. That pales in comparison to the 60-tonne Hoba meteorite in Namibia – but that fell to Earth around 80,000 years ago, long before recorded history. **AM**

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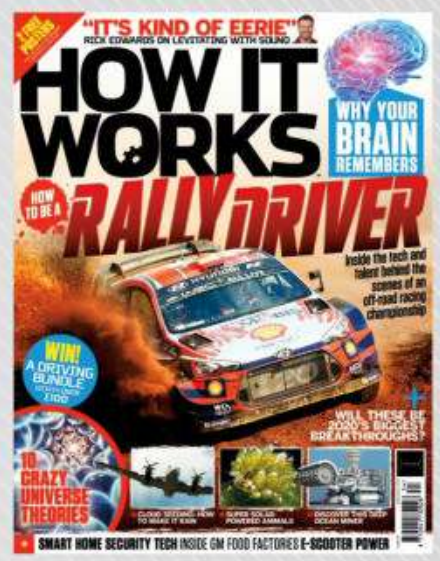
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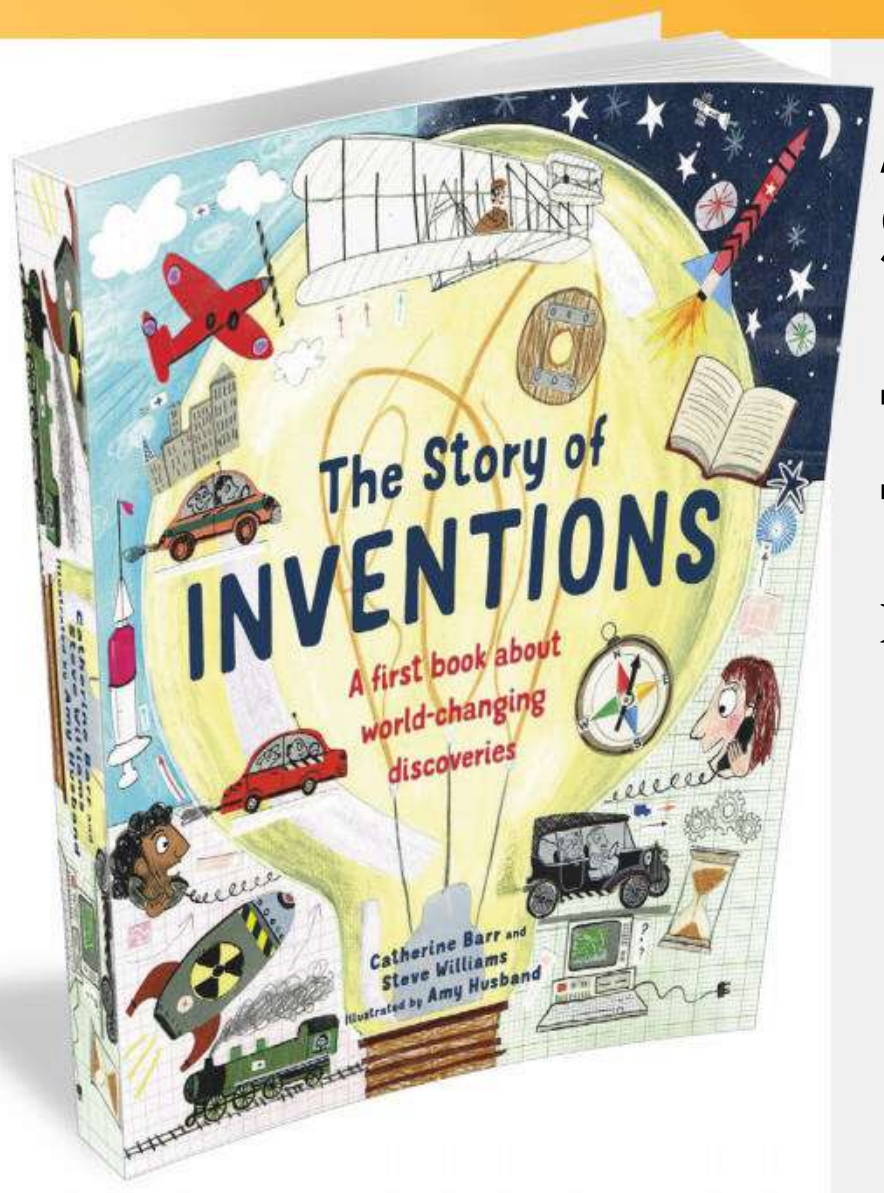
BOOK REVIEWS

The latest releases for curious minds



The Story of Inventions

A journey through time to discover the most world-changing discoveries

- Author: **Catherine Barr and Steve Williams**
- Publisher: **Frances Lincoln**
- Price: **£12.99 / $15.89**
- Release: **Out now**

For young kids the world is such a magical place, filled with endless unknowns. It's why they have so many questions about the things around them. And for parents looking to quench that thirst for knowledge, this history of important inventions will help. Covering everything from the wheel to the latest developments in computing, it whizzes through thousands of years in just over 30 pages.

The history here is definitely aimed at younger children – it's perfect for readers aged seven and up – and the writing is suitably basic. It doesn't go into huge detail on each topic, just giving a brief overview of each invention and explaining why they were so significant. That will probably be enough for many young readers, but some may come away wanting more. There's a handy glossary at the back of the book that will help explain some of the terms found, but there's still plenty of room for youngsters to find out more about a subject that's inspired them.

And there are sure to be some of those. The book groups inventions together, like showing the evolution of navigation from stargazing to GPS, or the path from steam power to renewable sources like solar and wind. A particular highlight is the page on plastics, which briefly shows why they were thought to be such an incredible invention at first before explaining how they're damaging the environment and polluting the seas. There are tips on how to avoid adding to this pollution, and lovely illustrations to hammer home how animals like turtles and dolphins can be injured by plastic in the oceans. It's not surprising to see lessons like these included in modern books for children, as they're essential topics for every generation to learn, but it's still praiseworthy to see it dealt with in such a well-considered way.

> "The history here is definitely aimed at younger children"

Those illustrations continue throughout the book. While fairly simple, the stylised design is really eye-catching, and paired with the bright colours and the sheer amount of stuff on every page, there really is plenty to look at – and lots of details to spot.

With a little more information about a few of the featured inventions this would've been even easier to recommend. As it is, it's still a great intro to the history of science for young readers – perfect for enquiring minds.

★★★★☆

Accidental Scientific Discoveries That Changed The World

Marvellous mishaps

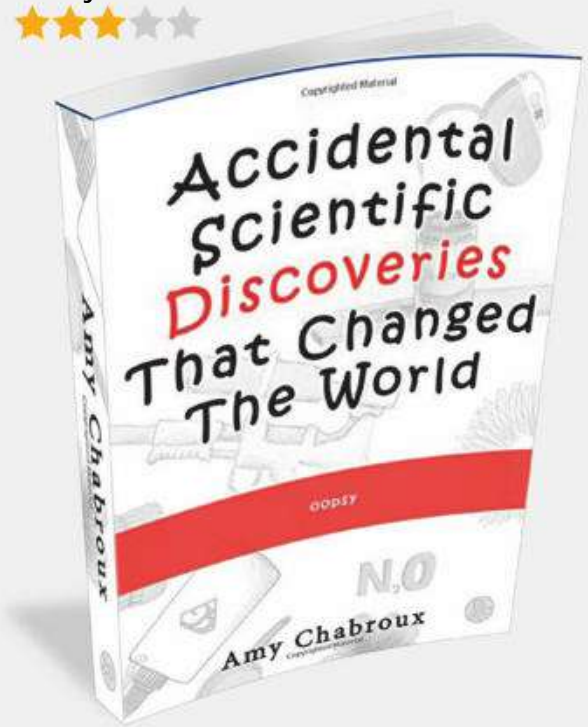
- Author: **Amy Chabroux**
- Publisher: **Independently published**
- Price: **£10.23 / $12.99**
- Release: **Out now**

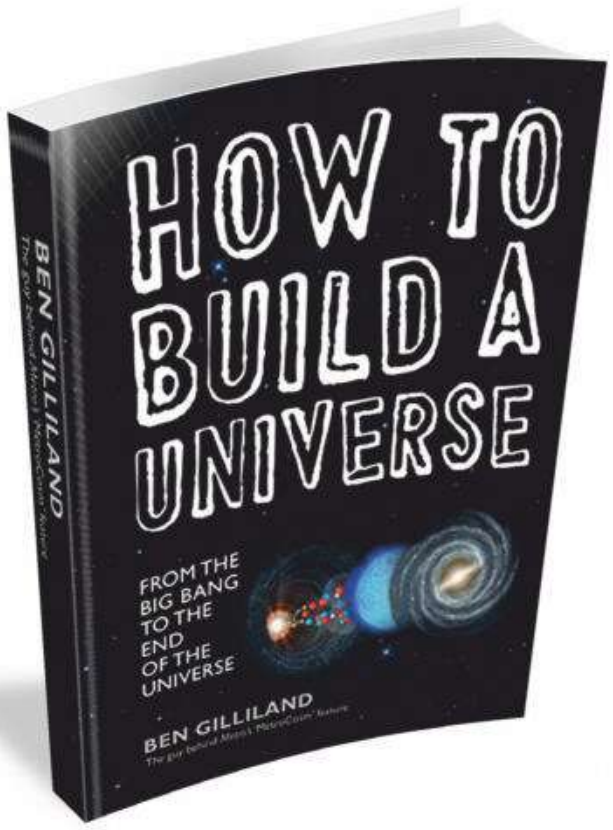
Generally we'd expect most scientific breakthroughs to be the result of many hours of painstaking research. While this is often the case, sprinkled throughout history there are also a number of discoveries that were initially little more than unexpected side-effects, but have become influential in their own right.

Both written and illustrated by Amy Chabroux, this book talks us through the processes that led to the discoveries of things like matches, X-rays, superglue and more. While the chapters are relatively brief, a sufficient amount of information is imparted that means readers should gain a decent understanding of the subject matter.

While this isn't the most in-depth book on the topic that we've seen – and the multiple Wikipedia articles in the bibliography don't exactly scream 'thorough research' – there's still a lot to like about this passion project, and it remains a worthwhile endeavour in our eyes.

★★★☆☆





How to Build a Universe

Generating greater galaxies

- Author: **Ben Gilliland**
- Publisher: **Philip's**
- Price: **£17.99 / $24.95**
- Release: **Out now**

Everyone knows about the Big Bang theory, but we suspect that far fewer can confidently state why it had the effect it did. Luckily, we've got Ben Gilliland – author of the *Metro* newspaper's popular MetroCosm column – on hand to fill in the blanks for us.

From the earliest observations of the ancient Greeks and figures like Copernicus and Galileo to the creation of the Solar System and the death of a star, Gilliland covers a lot of ground, going into a surprising amount of depth for such a small book. There's far too much information for us to list here, but suffice to say you're unlikely to be left unsatisfied.

Moreover, he even delves into some of the lesser discussed theories, namely those of the multiverse and bubbleverse, concepts you may have been forgiven for assuming existed purely in science fiction. Then there's the small matter of how we will eventually cease to exist – just be thankful it's a long way away!

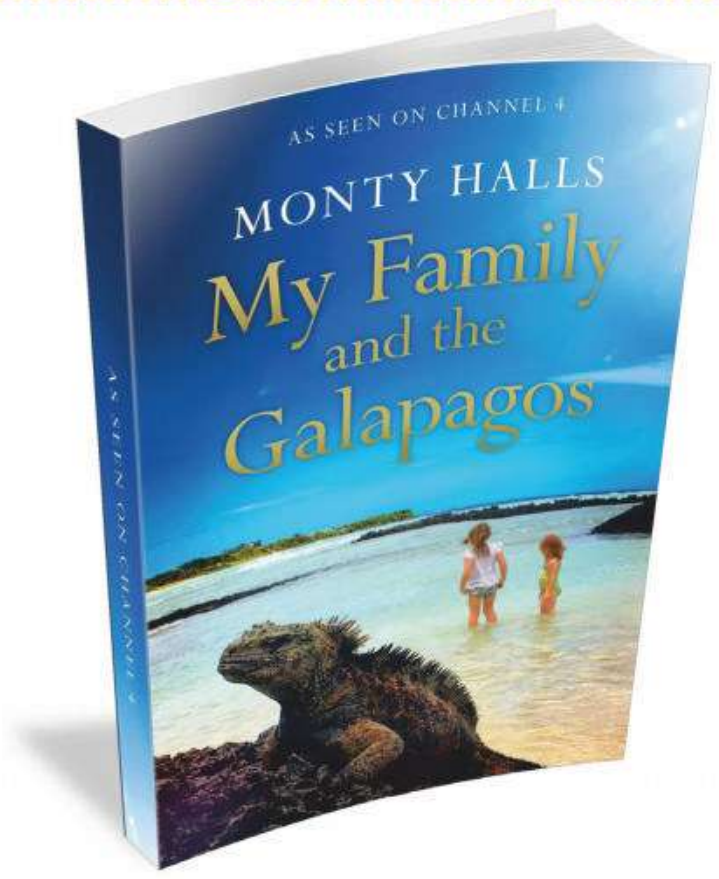
Packed full of facts and accompanied by an assortment of insightful illustrations, space enthusiasts will find a lot to enjoy here. As a basis for further reading it comes highly recommended.

★★★★☆

My Family and the Galapagos

Picking up in paradise

- Author: **Monty Halls**
- Publisher: **Headline**
- Price: **£20 / $23.95**
- Release: **Out now**

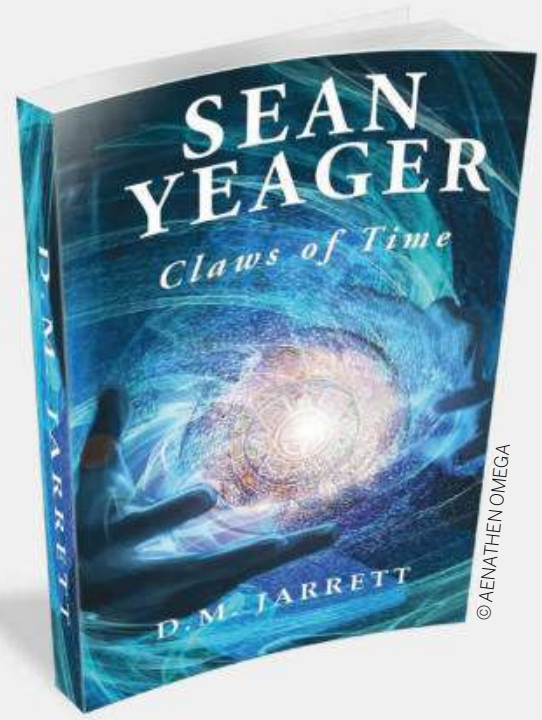


Monty Halls is a recognisable face on world nature-themed programming today thanks to his assorted appearances in television documentaries. This book is based on his most recent miniseries in which he and his family decamp to one of Earth's most evocative and vulnerable locations.

The focus is primarily on conservation here – rarely does a chapter go by without Halls pondering humanity's impact on the islands, from its bloody history post-discovery by the West to the lingering consequences of the increasingly imposing impact humankind has on the islands. In this regard, the presence of his two young children in the narrative is vital: they represent the future, which is in turn entwined with that of the Galápagos Islands.

Halls blends Bill Bryson-esque contextual anecdotes with a genuine earnestness for the subject matter in a manner that is seldom less than endearing. As such, we'd be hard-pressed not to recommend giving this a go.

★★★★☆



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Sean Yeager Claws of Time

The third book in the Sean Yeager series

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Sean Yeager Claws of Time is an adventure mystery for ages 8 to 14. Sean and Emily find a secret study at Kimbleton Hall and discover clues about Sean's missing father. After a close encounter on their way to school, they are offered the choice to rescue Major Clavity in Central America or to return home. They eagerly choose the mission. While Sean and Emily are in training, the Foundation begins to strain at the seams. Cassius Olandis races against time to find a long-forgotten relic that could help sustain his ailing body. Meanwhile, Darius Deveraux unleashes his masterplan on London. Unbeknownst to Sean and Emily, they hold the future of the world in their hands, and must decide who they can trust. Claws of Time is the third book in the Sean Yeager Adventures series.

"They hold the future of the world in their hands"

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 What's malware?
- Faulty online goods
- Broken pottery
- A type of virus detection software
- A malicious computer program

Q2 Which of these chemicals is not found in e-cigarettes?
- Carbon monoxide
- Nicotine
- Glycerin
- Propylene glycol

Q3 The first atomic bomb explosion was equivalent to:
- 20 tons of TNT
- 200 tons of TNT
- 2,000 tons of TNT
- 20,000 tons of TNT

Q4 Why are bees so important?
- They eat wasps
- They pollinate plants
- Honey is an important food source for all
- Beekeepers wouldn't have jobs without them

Q5 The world's fastest train can travel at:
- 125mph
- 175mph
- 275mph
- 375mph

Q6 What was Sputnik?
- A manned spacecraft
- An asteroid
- A satellite
- A heavy rocket

Spot the difference

See if you can find all six changes between the images below

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

6	9						2	1
				3	2			8
	8	2	4			5		
4		5		8	1	7		6
	7				4		8	3
	1	3		7		2	5	4
		1	7				4	
7		8	1			9	3	2
5	3			4	8			

DIFFICULT

5	9							
			6					5
	7					2		
		7				9	2	3
			2			7		8
		8	5		9			
7		5			2			
4	2	6	1					
		9			7	1		

What is it?

Hint: The dimples on this object make it more aerodynamic when airborne

A .....

A	T	D	W	L	N	X	U	P	O	I	N	D	E	C
S	D	E	T	E	C	T	O	R	N	U	F	O	I	G
X	O	J	I	U	Q	A	G	S	C	R	W	B	V	A
R	B	A	Z	Z	I	P	X	L	Z	T	G	E	A	L
K	C	N	A	P	G	M	E	X	Z	S	O	X	Y	A
D	T	N	M	O	H	A	E	K	B	A	L	S	I	P
D	O	E	B	A	R	J	C	L	H	T	D	E	W	A
O	X	L	Q	C	Z	U	T	O	I	E	P	V	K	G
S	R	I	Z	Z	I	S	N	R	A	L	M	A	T	O
B	E	D	I	W	O	I	A	Q	O	L	Y	D	I	S
R	U	O	X	P	E	P	U	H	C	I	F	T	I	M
S	E	I	M	R	F	L	E	H	F	T	E	K	D	O
A	H	O	E	E	T	D	V	A	P	E	I	Y	D	X
T	C	S	L	R	E	K	T	M	U	V	K	S	Q	L
F	D	J	M	O	N	A	R	C	H	Y	P	Q	Z	Y

Wordsearch

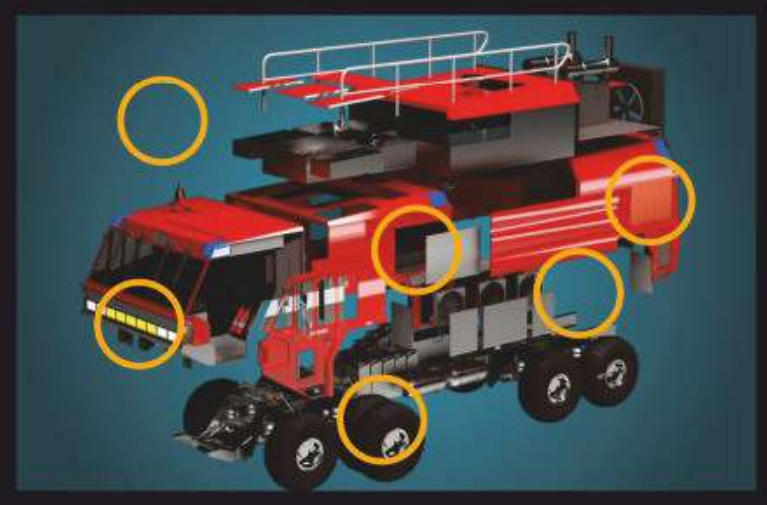
FIND THE FOLLOWING WORDS...

DDOS
COMPOST
PIZZA
GOLD
VAPE
GALAPAGOS
SATELLITE
DETECTOR
HAM
ANNELID
NUCLEAR
MONARCHY

Check your answers

Find the solutions to last issue's puzzle pages

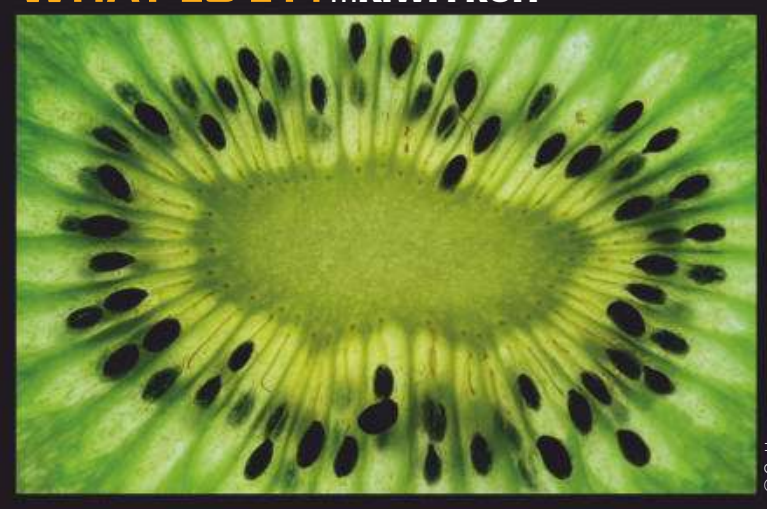
SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 1,000
Q2 He was nearest the door
Q3 Whisky
Q4 Spray it with dry powder
Q5 Polaris
Q6 It's radioactive

WHAT IS IT?...KIWI FRUIT



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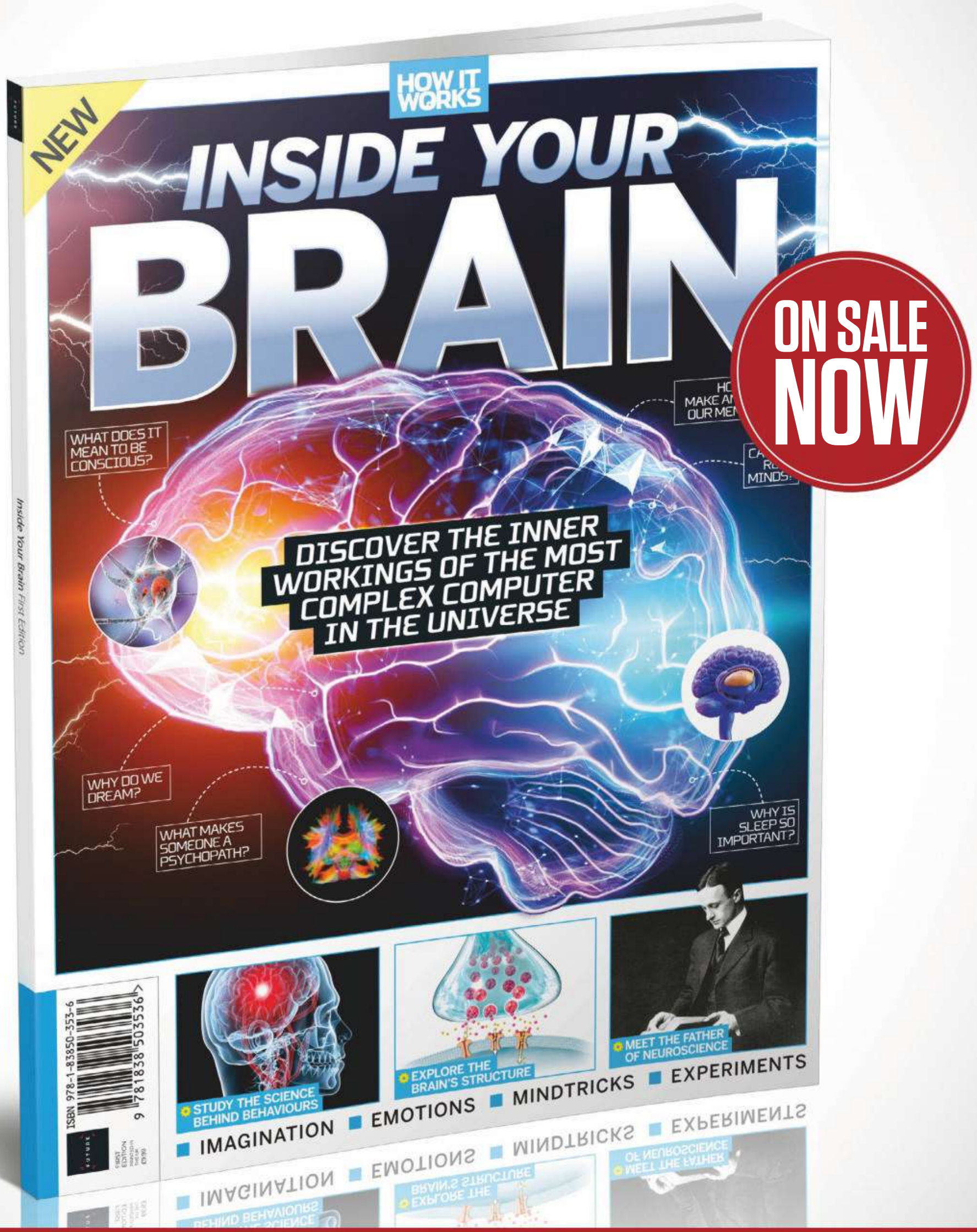

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Build a bug hotel

Create a hiding place for the wildlife in your garden from all-natural materials

1 Pick a spot

Choose a flat, firm part of your garden to build your hotel. Where you choose will decide what kind of wildlife you attract: some prefer damp, cool conditions, while others will prefer the Sun.

2 Find your structure

Your structure needs gaps so creatures can get in and out. Old wooden pallets are a great choice – ask an adult to help chop them up. If you don't have any you can use planks instead.

3 Build it up

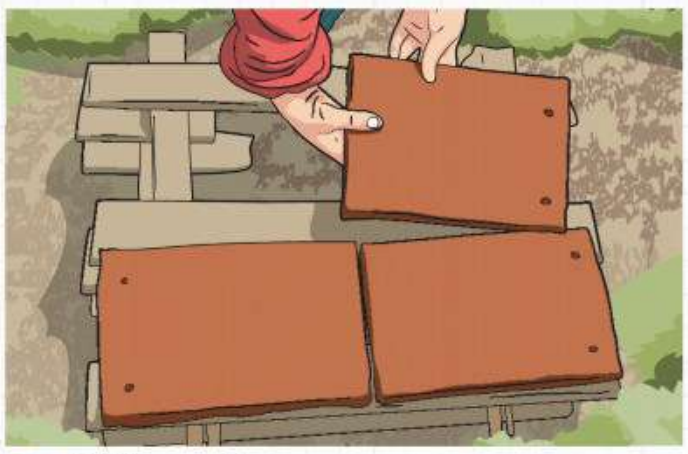
Place four bricks on the ground to form a solid base for your hotel, then start to pile the wooden pallets on top. Leave some space in the bottom layer to encourage hedgehogs to stop by.

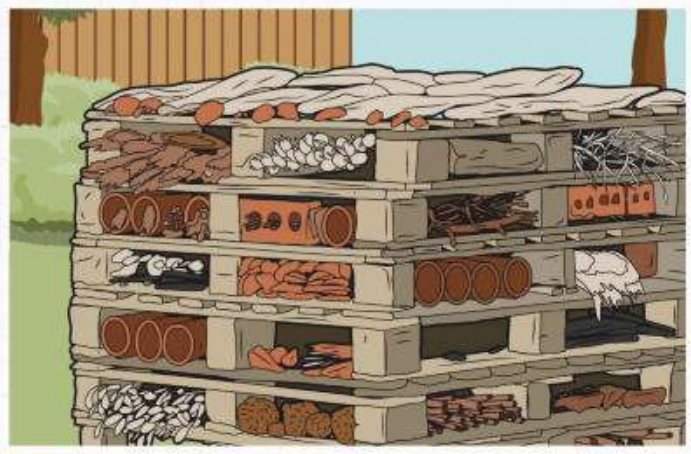
4 Customise your hotel

You can build your hotel as high as you like – just make sure it's sturdy. Or you can make a smaller structure to encourage smaller creatures to come and visit. Try building it by a tree for more cover.

5 Fill the gaps

The goal is to provide plenty of small hidey holes for creatures to nestle in. Use things like tree bark, stones, dry leaves and even corrugated cardboard. You could also add a hedgehog box in the base.





6 Add a roof

Top off your hotel with a waterproof 'roof' – something like tiles or planks covered in roofing felt. You can even sprinkle some rubble or gritty soil up there to encourage some greenery to grow.

7 Make it inviting

To encourage more critters to call at your hotel, surround it with nectar-rich flowers. That'll bring bees, butterflies and other flying insects, and provide cover to smaller ground-based bugs.

SUMMARY

Minibeasts are everywhere in your garden, but you can bring them all together with a hotel that caters for different species. Woodlice, spiders, beetles and centipedes like loose bark and leaves, while large holes and stones offer frogs a place to keep cool. And try drilling holes in wood to give lonely bees a place to shelter.

Had a go? Let us know!
If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

NEXT ISSUE
Build a hybrid rocket engine using pasta

© Illustrations by Ed Crooks

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INBOX
Speak your mind...

Stromatolites can be found in the shallow waters of Shark Bay in Western Australia

© Ailsa Harvey

Studying stromatolites

Hi **HIW,**

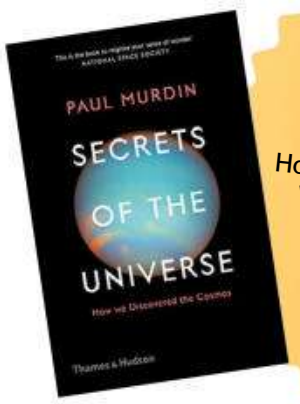
I have read with interest the feature on page 15 in issue 131 of **How It Works**. The feature by Mindy Weisberger is interesting, but what she doesn't mention is the fact that there are some rare living remains of stromatolites which survive to this day. They are most accessible at Sharks Bay on the northwest coast of Australia, and less so at a remote coral cay in the Bahamas.

As Mindy would probably be aware, as part of their photosynthesising process the cyanobacteria, which together form the rock-like stromatolites, give off minute quantities of oxygen. With their widespread presence around the world 3.5 billion years ago, it is acknowledged that they raised the Earth's atmospheric oxygen levels to 20 per cent, and as such were the precursors to the development of other more complex life forms – including humans.

Peter Staveley

Thank you for your comments on one of our previous issues. In issue 131's Global Eye we learned about stromatolites and how analysis of Australia's ancient rock revealed a snapshot of what microbial life was around 3.5 billion years ago.

While this story focuses on one study, there are existing stromatolites dotted around the world. Stromatolites are layered biochemical structures which usually form in extremely salty lagoons. While nearly extinct in marine environments today, there have been examples found in Australia, the Bahamas, the Indian Ocean and the US.



WIN!
SECRETS OF THE UNIVERSE
How did our universe come to exist? Why do stars shine? Is there life beyond Earth? In *Secrets of the Universe*, world-renowned astronomer Paul Murdin tells the stories of key astronomical discoveries

Get in touch

If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag howitworks@futurenet.com

Letter of the month

The science of *Star Wars*

Hi **HIW,**

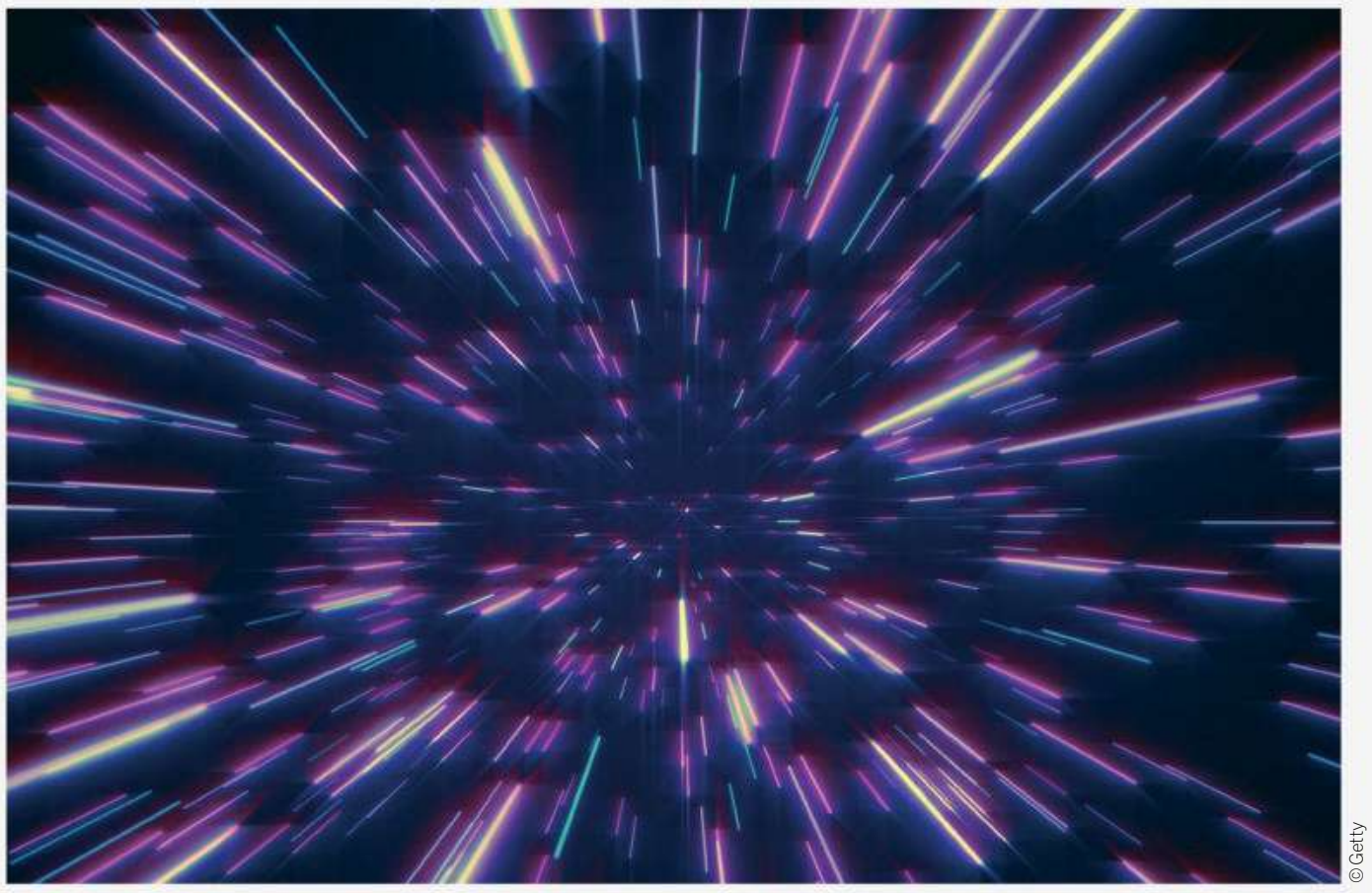
I'm 11 years old and have been getting your magazine for six years. I'm a huge fan of sci-fi such as *Star Wars* and my question is: what would happen if a physical object went over the speed of light. Keep up the hard work and keep the magazine as good as ever!

Alfie

In *Star Wars* there is an alternative dimension referred to as 'hyperspace'. How do you get there? You have to send your spaceship travelling faster than the speed of light. This effect looks awesome in the movies and, as it has for you, can leave us wondering what it would actually be like to travel this way.

Physical objects cannot endure light speed, proved by Einstein's equation $E=mc^2$. With E representing energy, m the mass of an object and c the speed of light, the equation shows that as a physical object gains energy through motion, it needs to gain mass. By the time an object reaches 90 per cent of the speed of light, its mass would double. If anything could achieve the speed of light, its mass would become infinite. As the equation shows, an infinite mass requires infinite energy to achieve the speed of light. In reality, an infinite energy supply cannot be localised to one mass, but spread across infinite space and time. Not only could an object not exceed light speed, it wouldn't even reach it.

If you managed to combat this impossibility and reach 90 per cent of the speed of light, your vision would turn to a tunnel view as all light would appear to come only from in front of you, like a spotlight. This happens because light photons from all around you would all be viewed in one place, a phenomenon called relativistic aberration.


© Getty

'Hyperspace' is a fictional sub-region of space that exists alongside our own

Correction

In issue 133 of **How It Works**, the image spread entitled 'Face cream gets a close-up' on pages six and seven showed tantalising tessellations of naturally occurring crystals in a popular face cream. The array of intermingling colours are the result of a phenomenon called birefringence, whereby light is split into two components. However, the image was incorrectly credited in the text: the photographer and copyright holder of the photo is Karl Gaff.

© Karl Gaff

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NEXT ISSUE...
Issue 137 on sale
16 APRIL 2020

Space living

Hi **HIW,**

I am a Chinese reader and I really like reading **HIW** very much. Recently I read some articles about searching for life beyond the Earth. From Mars to Kepler 452b, it is a great mission and meaningful to human beings. However, the universe is so huge that even a teeny tiny clue of life could be a big discovery, not to mention finding out a planet is fit for people to inhabit.

Here is a problem, and it is widely disputed on the internet. If our scientists just want to find some extraterrestrial life, their ways may be not that good or objective. According to these articles, if a planet has water, oxygen and moderate temperature, there may probably exist life on the planet. But wait, does extraterrestrial life really need water and oxygen to survive? Maybe what they need is actually carbon monoxide! Oxygen? Dangerous and lethal! It can only be used when they want to kill themselves. I do know our scientists are 100-times smarter than us; they may have noticed this question at the very beginning, but why do they still insist on finding extraterrestrial life under these very restricted conditions?

Thank you for your letter. Life on other planets has always been something that has intrigued us. How much is out there that we don't know about? You make an interesting point that we don't know what other living beings need if we haven't encountered them yet – but we can only go on what we know. And to find any sign of life living similarly to the way we do, our best bet is to start looking for what we already know life needs. That being said, who knows what we could find through other space missions when we aren't looking specifically for evidence of life?

What's happening on... social media?

INSTAGRAM

This month we started sharing an interesting fact a day with our Instagram followers. We chose this as our post of the month as we loved to hear some of your thoughts and stories about the invention of the microwave.

The microwave was invented by accident when an engineer walked past a radar tube and his chocolate bar melted in his pocket
HOW IT WORKS

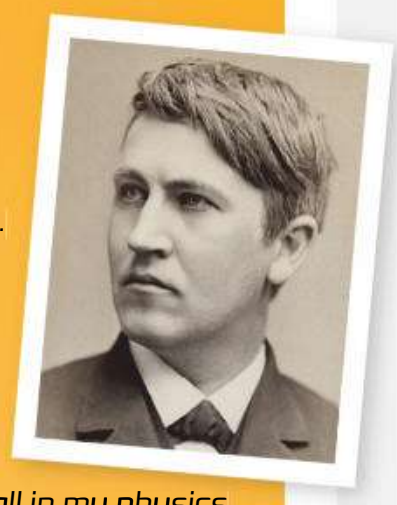
Follow **@howitworksmag** on Instagram for a daily fact like this one

@mgela80
I don't know exactly how it affects our body but I read somewhere that the microwaves are changing the structure of the food and it hasn't got the same taste after. My personal experience is that since I have stopped using the microwave my bad headaches have disappeared.

@ruthbarrens
My dad was an electronics engineer and one of the early pioneers in RADAR [Radio Detection and Ranging]. Once, when we drove past some sort of RADAR equipment, and long before microwave ovens, he jokingly said, "Anybody want to roast a chicken?"

TWITTER

This month we asked you: "If you could meet any scientist – from the past or present – who would you want to meet?"



@marnoldquips
I think a conversation with Thomas Edison would be very interesting. It would be cool to get a glimpse into how his mind ticked.

@vincenta21
Isaac Newton. He was looking at me from the wall in my physics classroom. It would be great to ask him about his alchemy studies and about his laws of motion.

@steevojohno
Engineers of the latest CPU, GPU and programmers, genius.

@lyddenpat
Elizabeth Garrett Anderson, the first English woman doctor.

@helenharding83
I'd like to meet Brian Cox because he makes space exciting.

HOW IT WORKS

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10 MARCH 1535

FRAY TOMÁS DE BERLANGA DISCOVERED THE GALÁPAGOS ISLANDS BY ACCIDENT WHILE SAILING TO PERU

27,000

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£9,000

THE PRICE OF THE WORLD'S MOST EXPENSIVE PIZZA

36

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Jaguar I-PACE eTROPHY
Build an Iconic Model

The all-electric Jaguar I-PACE has completed an historic treble at the 2019 World Car Awards. Not only has it won the coveted 2019 World Car of the Year and World Car Design of the Year titles , it has also been named World Green Car.

The I-PACE is the first model ever to win three World Car titles in the 15-year history of the awards.

The dramatic, cab-forward profile, short overhangs and taut, muscular haunches give it a sense of drama which set it apart from other SUVs, which when building with the 40 pieces included you will see as the car grows before you.

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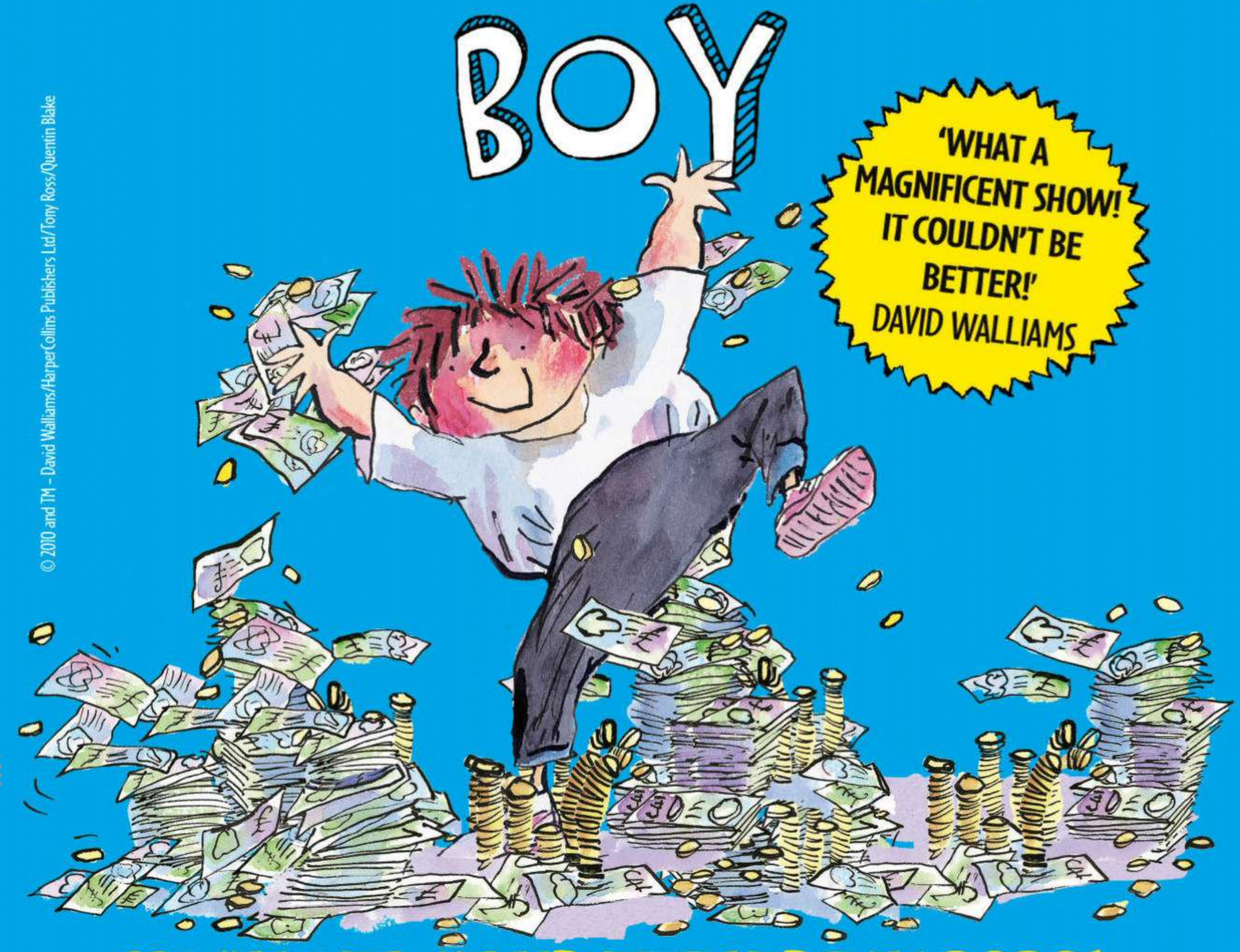

'WHAT A MAGNIFICENT SHOW! IT COULDN'T BE BETTER!' DAVID WALLIAMS

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